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AQUATIC INVERTEBRATE STUDY

AQUATIC INVERTEBRATE STUDY

BELT/SAND COULEE DRAINAGES
AND
MISSOURI RIVER

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1. Aquatic invertebrate study

Contents

Figures

Tables

I. Introduction

An investigation of impacts from abandoned underground coal mines in Sand Coulee and Belt Creek areas resulted in a study of the aquatic biology in each drainage. This study was commissioned by the Department of State Lands (DSL) and funded through the Office of Surface Mining.

Uncontrolled drainage from underground mining has the potential to cause significant water quality problems. Investigations of qualitative and quantitative changes in aquatic macroinvertebrate communities are a means to evaluate the severity of these problems. Effects on natural waters which come in contact with mine drainage or tailings from mines include: reduced pH, high concentration of certain heavy metals, and increased sediment loads. The water's chemistry, in some instances, can render it unsuitable for habitation by aquatic life.

Macroinvertebrate populations are useful to evaluate the quality of water in streams. They are probably best suited for this purpose because they are numerous in almost every freshwater lotic environment. Invertebrates are essential because they comprise the energy link between periphyton and fish in most aquatic food systems.

Due to differing environmental perferences and tolerances, limited mobility and relatively long life span, invertebrates reflect the water quality conditions of the recent past. Unlike physical and chemical determinations which evaluate specific characteristics of the water only at the moment of sampling, macroinvertebrates integrate or are a function of the entire spectrum of water quality constituents over a period of time.

In a well balanced ecological system virtually all trophic levels will likely be occupied by benthic arthropods. A non-polluted environment

supports a large number of different kinds of invertebrates with each kind represented by a relatively small number of individuals. When low concentrations of organic pollution occur, invertebrates intolerant of such pollution decrease in number and, in some cases, disappear from the community. Organisms more tolerant in their sensitivities to organic pollution tend to increase in number, increasing the total number of organisms while diversity may decrease. Severe organic pollution can make water uninhabitable to all but a few very tolerant organisms.

Toxic materials may reduce diversity and populations of aquatic organisms; but, unless pollution is quite severe, different kinds of invertebrates may not be reduced significantly. Diversity values may show improvement in the effected area when compared to upstream or other control stations. Generally, as toxic materials proceed downstream and are diluted, the benthic community increases in population, diversity, and overall biomass. Combinations of toxic or organic pollution can cause a variety of effects.

No single benthic species exists to simplify interpretations relating to the state of conditions in the aquatic environment. Presently, many immature stages of invertebrates are not keyed taxonomically to the specific level. Gaufin (1973) emphasizes, however, that relative abundance estimates of species, or the percentage of individuals in each separate taxon per sample, are more useful in evaluating conditions in streams than the presence or absence of a particular species. Also, Cummins (1974) points out some problems that are inherent in species recognition that can be alleviated by recognizing functional groups of organisms based on their feeding mechanisms. Feeding mechanisms include: siezing, scraping, filtering and sucking, either simple ingestion of the substratum or plant and animal tissues.

Often the predominance of a type of feeding mechanism can be functionally related to the basic trophic level which prevails within various sections of a stream.

All the attributes and parameters used in evaluating the invertebrate component are useful, but no particular one describes a community completely. A balance of physiochemical and biological techniques and interpretations is required to provide a cohesive data base.

II. Description of study areas and sampling stations

A. Belt Creek

Belt Creek originates on the north slope of the Little Belt Mountains approximately fifty-five miles southeast of Great Falls, Montana. It flows generally in a northwest direction and terminates in the Missouri River north of the city just downstream of Morony Dam.

The study area focused on a twelve to fifteen mile section of stream located in the vicinity of the town of Belt. A sampling station was also located near the confluence of the stream with the Missouri River to assess the aquatic life in the lower third of the stream and to determine if it varied significantly from the more intensively sampled upstream portion (Figure 1).

B. Sand Coulee Creek

Sand Coulee Creek originates in foothills about twenty-five miles south of Great Falls. It flows in a northwest direction, joining the Missouri River just outside the southern boundary limit of the city.

The study area focused on the upstream tributaries of the creek south of Tracy. The downstream portion of the stream was dry during much of the study period (Figure 2).

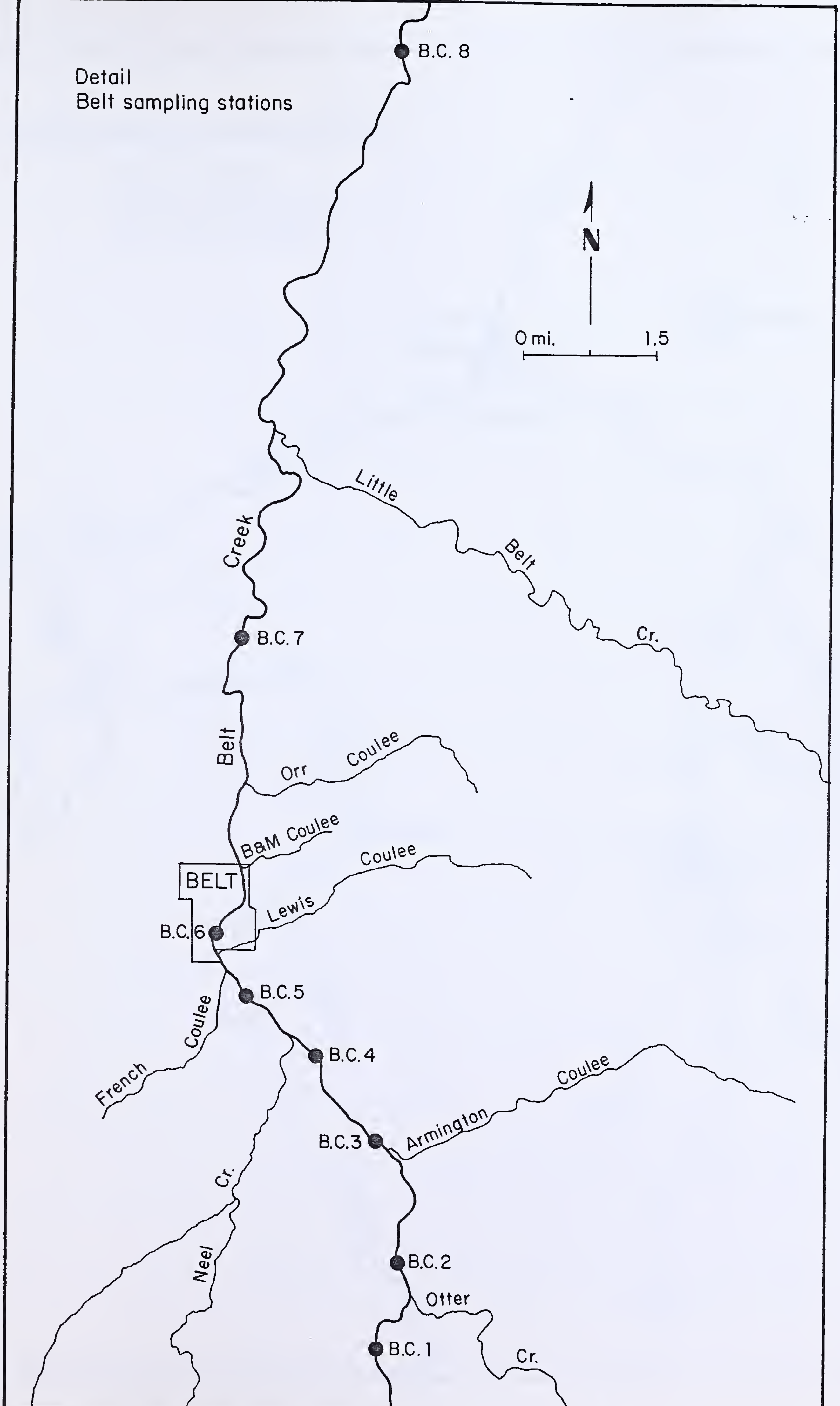


Figure 1. Sampling stations, Belt Creek drainage

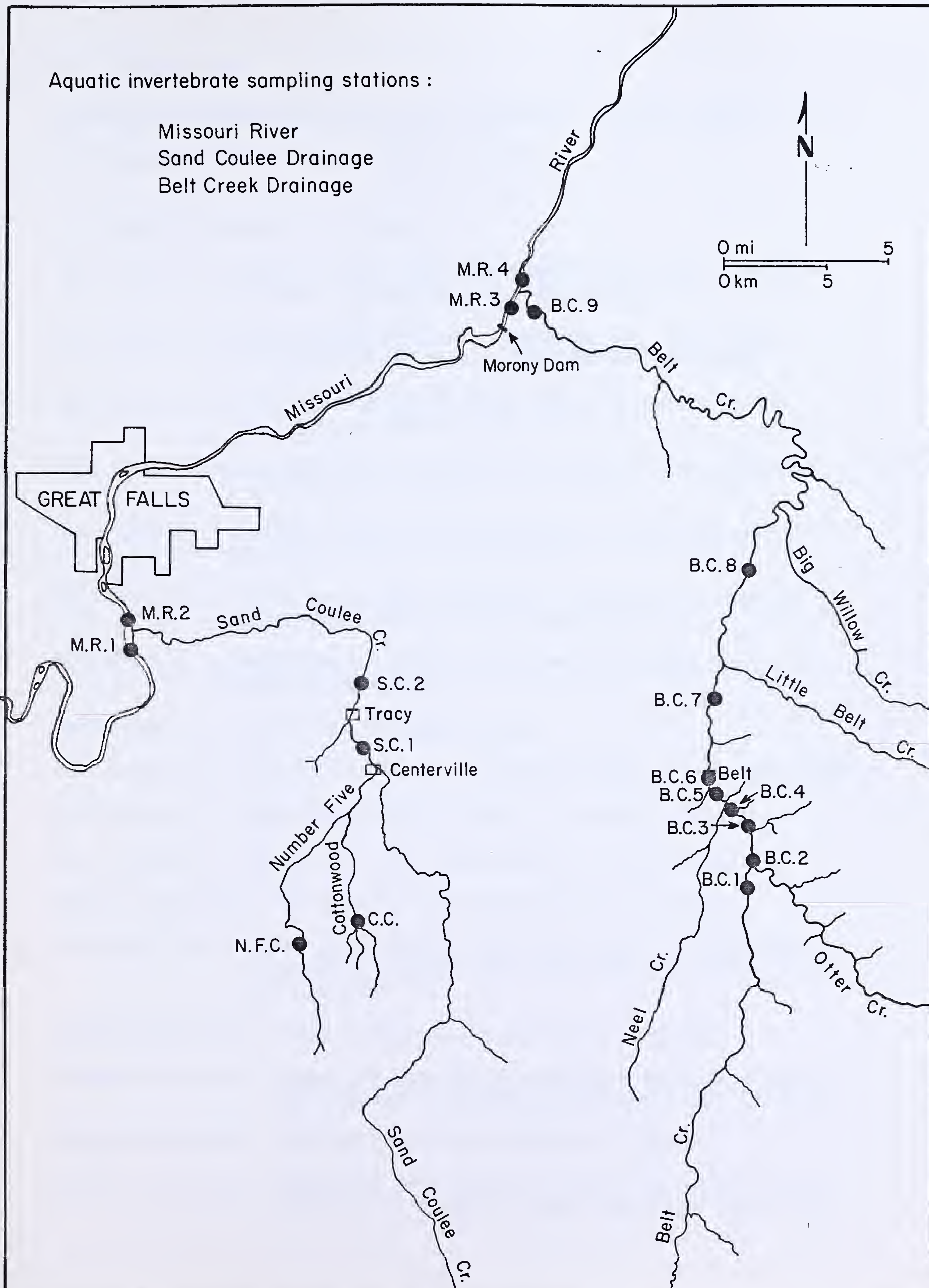


Figure 2. Sampling stations, Missouri River, Sand Coulee drainage, Belt Creek drainage

C. Missouri River

Upstream and downstream stations were sampled at the confluences of both Sand Coulee and Belt Creeks (Figures 1 and 2).

D. Sampling station descriptions

Belt Creek #1 - upstream Otter Creek approximately 200 meters, upstream Armington Junction of Hwys. 89 and 200

Belt Creek #2 - downstream Otter Creek, downstream Hwy. 200 bridge approximately 150 meters, upstream mining impacts

Belt Creek #3 - downstream Armington Coulee about 300 meters at the Ft. Ponderosa campgrounds

Belt Creek #4 - upstream Neel Creek about 200 meters at Virgil Nelson's ranch near the cemetery

Belt Creek #5 - upstream French and Lewis Coulee and upstream mine tailings on south side of Belt

Belt Creek #6 - at the footbridge downstream of the mine tailings and upstream B&M Coulee in the town of Belt

Belt Creek #7 - downstream Orr Coulee, upstream from bridge about 20 meters on Ewing road

Belt Creek #8 - across from the Bowman Ranch

Belt Creek #9 - upstream from mouth 400 meters on the C.L. Urquhart Ranch

Sand Coulee #1 - downstream bridge 20 meters at Centerville School

Sand Coulee #2 - downstream Tracy approximately 1 mile on farm road

Number Five Coulee - downstream Giffin Spring about 50 meters

Cottonwood Creek - east approximately 1 mile from where blacktop ends on hwy. 227 in farmers yard approximately 4 miles south of Stockett

Missouri River #1 - upstream Sand Coulee confluence 25 meters

Missouri River #2 - downstream Sand Coulee confluence 25 meters (access at Jack Keating's residence at Brookwood Park Estates)

Missouri River #3 - upstream Belt Creek confluence 25 meters

Missouri River #4 - downstream Belt Creek confluence 100 meters (access at Mrs. C.L. Urquhart's ranch downstream Morony Dam)

III. Methods

Sampling was performed in riffle areas where the water ranged from 30 to 45 cm (12 to 18 inches) in depth and the substrate was composed of small rubble ($2\frac{1}{2}$ to 6 inches) interspersed with gravel and finer sediments.

Quantitative samples were collected from Sand Coulee and Belt Creeks on July 10-12, August 28-31, and November 19-21, 1980, using a modified Surber square foot sampler (Figures 1 and 2). The sampler netting is 210 micro-mesh, has a bag length of three feet and can be used in up to eighteen inches of water. Sampler contents were sieved in a U.S. Standard No. 70 sieve and the organisms remaining on the sieve placed in 6 ounce jars and preserved in 95 percent ethanol. Three replicate samples were taken at each station during each time period.

Missouri River stations were sampled using the Surber sampler and also by multi-plate artificial substrates that were exposed for six weeks. The substrates were constructed of 0.64 x 5.1 x 5.1 cm (1/4 x 2 x 2 inch) masonite plates. Eleven plates were mounted on a 0.64 cm diameter threaded rod and separated by ten 0.64 x 2.5 x 2.5 cm (1/4 x 1 x 1 inch) masonite spacers, thus exposing approximately 0.065 square meters (0.7 square foot) of substrate for attachment by aquatic organisms. Macroinvertebrates were removed, sieved, and preserved in 95 percent ethanol for later identification.

Aquatic macroinvertebrates were identified to the lowest practical taxonomic level (usually genus) utilizing keys written by Bauman et al (1977), Brown (1972), Edmunds et al (1976), Jensen (1966), Johannsen (1934, 1935), Merritt and Cummins (1978), Oliver et al (1978), Usinger (1971), and Wiggins (1977).

Macroinvertebrate species diversity and distribution of individuals among

species were computed using the machine formula of the Shannon-Weaver function. (Lloyd, Zar, and Karr, 1968) for calculating mean diversity ($\bar{d}$). The formula for computation is as follows:

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \sum_{i}^{s} ni \log_{10} n_i)$$

where; $\bar{d}$ = mean diversity

$c = 3.321928$ (converts base 10 log to base 2)

N = total number of individuals

n_i = total number of individuals in the i^{th} species

s = total number of taxa

Equitability (e) of collected benthic invertebrates was computed following the method proposed by Lloyd and Gherlardi (1964). This measure of the distribution of abundance is expressed by:

$$e = \frac{S^1}{S}$$

where; s = the number of taxa in the sample

s^1 = the number of expected taxa, a tabulated value from Lloyd and Gherlardi (1964)

IV. Results and discussion - Belt Creek

Data from the study area indicated that Belt Creek contains the combination of nutrient enrichment and effects of insidious or chronically toxic materials working together in the system. Figure 3 and Table 1 demonstrate the effects of this combination.

Benthic organisms collected at the upstream control station (Station 1) (Figure 4) show a diverse number of taxa as well as acceptable total numbers per sample. Slight stress is indicated, however, from diversity and equitability values (Figure 5 and Table 2); in unpolluted waters $\bar{d}$ is usually

Table 1. Precent relative abundance of major macroinvertebrate orders encountered on Belt Creek per station per month.

Order	Plecoptera (Stoneflies)				Ephemeroptera (Mayflies)				Trichoptera (Caddisflies)				Coleoptera (Beetles)				Diptera (Trueflies)			
Station	July	Aug.	Nov.	Mean	July	Aug.	Nov.	Mean	July	Aug.	Nov.	Mean	July	Aug.	Nov.	Mean	July	Aug.	Nov.	Mean
#1	17	11	13	14	32	24	16	24	25	39	36	33	1	1	1	1	25	25	28	26
#2	27	9	20	19	16	16	17	16	27	45	25	32	2	2	4	3	25	54	34	38
#3	18	12	18	16	40	38	28	35	15	32	28	25	4	1	2	2	23	16	16	18
#4	10	8	10	13	18	22	7	16	5	43	53	34	2	3	16	7	65	24	15	35
#5	4	8	16	9	13	30	16	20	7	33	7	16	1	4	19	8	73	28	43	48
#6	15	21	25	20	13	14	14	14	47	24	20	30	4	6	20	10	19	35	16	23
#7	9	7	3	6	52	11	14	26	6	62	74	47	3	5	5	4	28	16	4	16
#8	5	6	7	6	26	15	22	21	42	63	57	54	4	5	2	4	22	6	10	13
#9		3	2	3		18	47	33		57	37	47		3	1	2		19	13	16

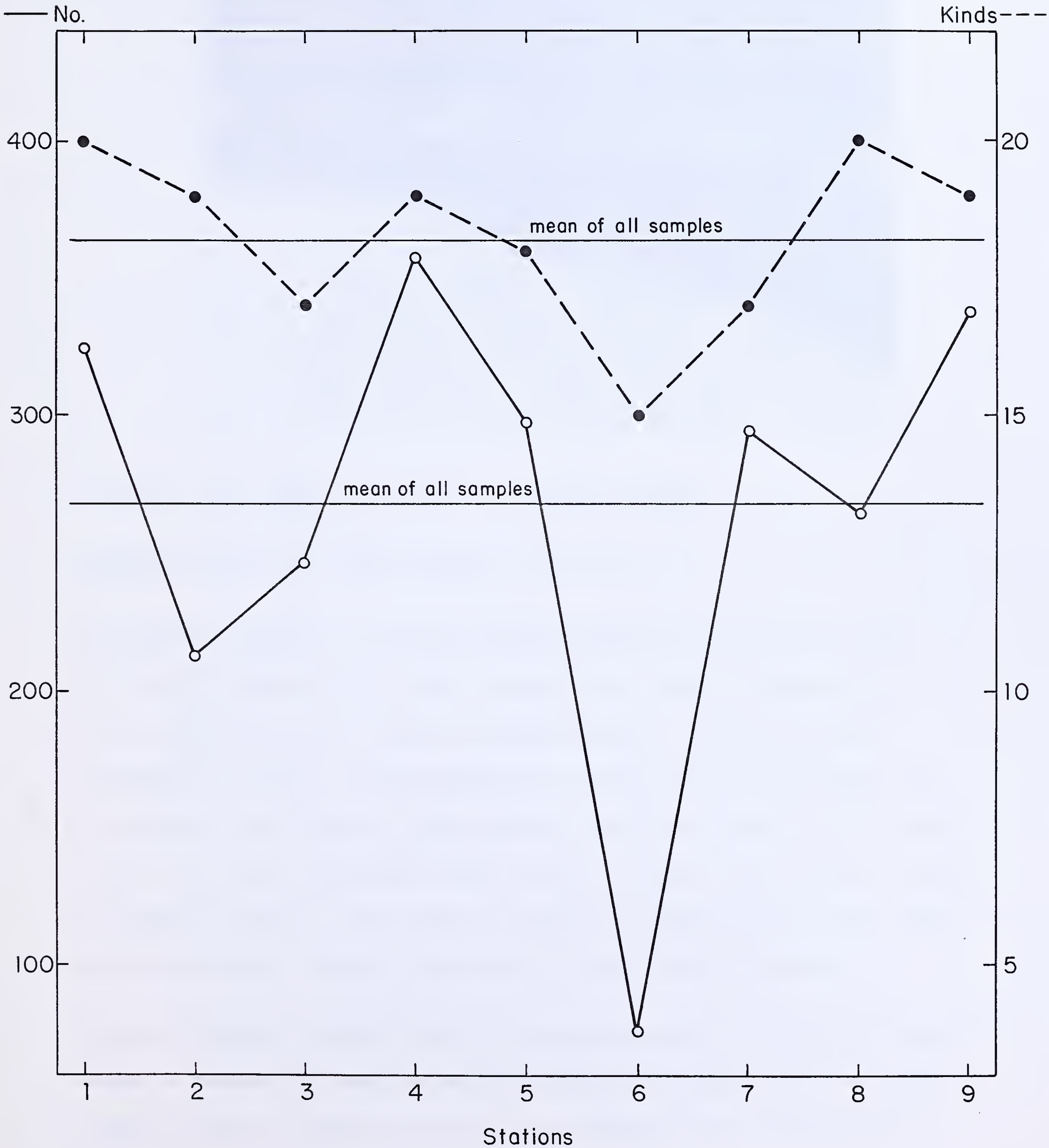
Table 2. Mean diversity ($\bar{d}$) and equitibility (e) for each station for each month sampled on Belt Creek.

Station	July		August		November		Mean per station	
Numbers	$\bar{d}$	e	$\bar{d}$	e	$\bar{d}$	e	$\bar{d}$	e
#1	1.85	0.22	2.88	0.45	3.69	0.75	2.81	0.47
#2	3.63	0.72	2.81	0.41	3.58	0.79	3.34	0.64
#3	3.38	0.75	2.93	0.53	3.56	0.77	3.29	0.68
#4	2.76	0.39	3.03	0.48	3.78	0.95	3.19	0.61
#5	1.96	0.23	2.92	0.46	3.42	0.62	2.77	0.44
#6	3.54	0.93	3.75	0.98	3.74	0.97	3.68	0.96
#7	3.12	0.54	2.83	0.43	2.35	0.56	2.77	0.51
#8	3.31	0.55	3.08	0.55	3.04	0.47	3.14	0.52
#9			2.89	0.52	3.52	0.66	3.21	0.59

Table 3. Mean numbers of macroinvertebrates collected per sample per month for each station on Belt Creek.

Station	July	August	November	Mean/Station
#1	322	509	145	325
#2	245	300	95	213
#3	180	336	221	246
#4	262	541	270	358
#5	403	370	118	297
#6	119	66	44	76
#7	172	255	455	294
#8	316	190	290	265
#9		273	402	338
Mean/month	252	316	227	

Figure 3. Mean Numbers of Sub-ordinal Taxa (kinds) and Numbers of Macroinvertebrates (No.) collected per sample, Belt Creek at each station



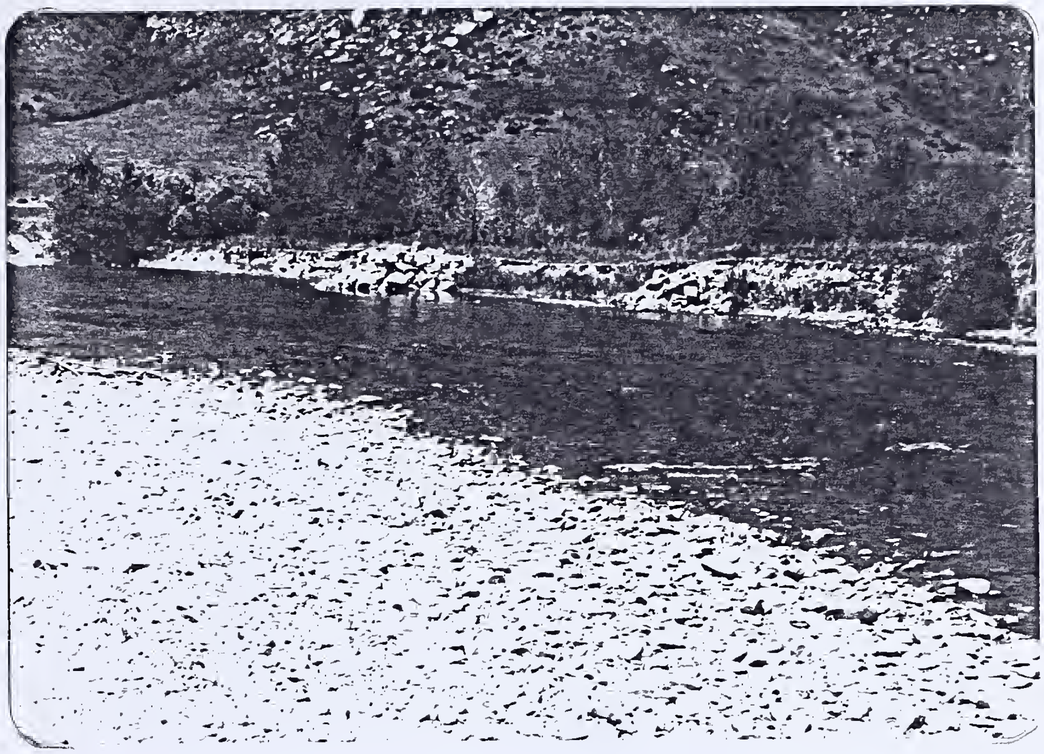


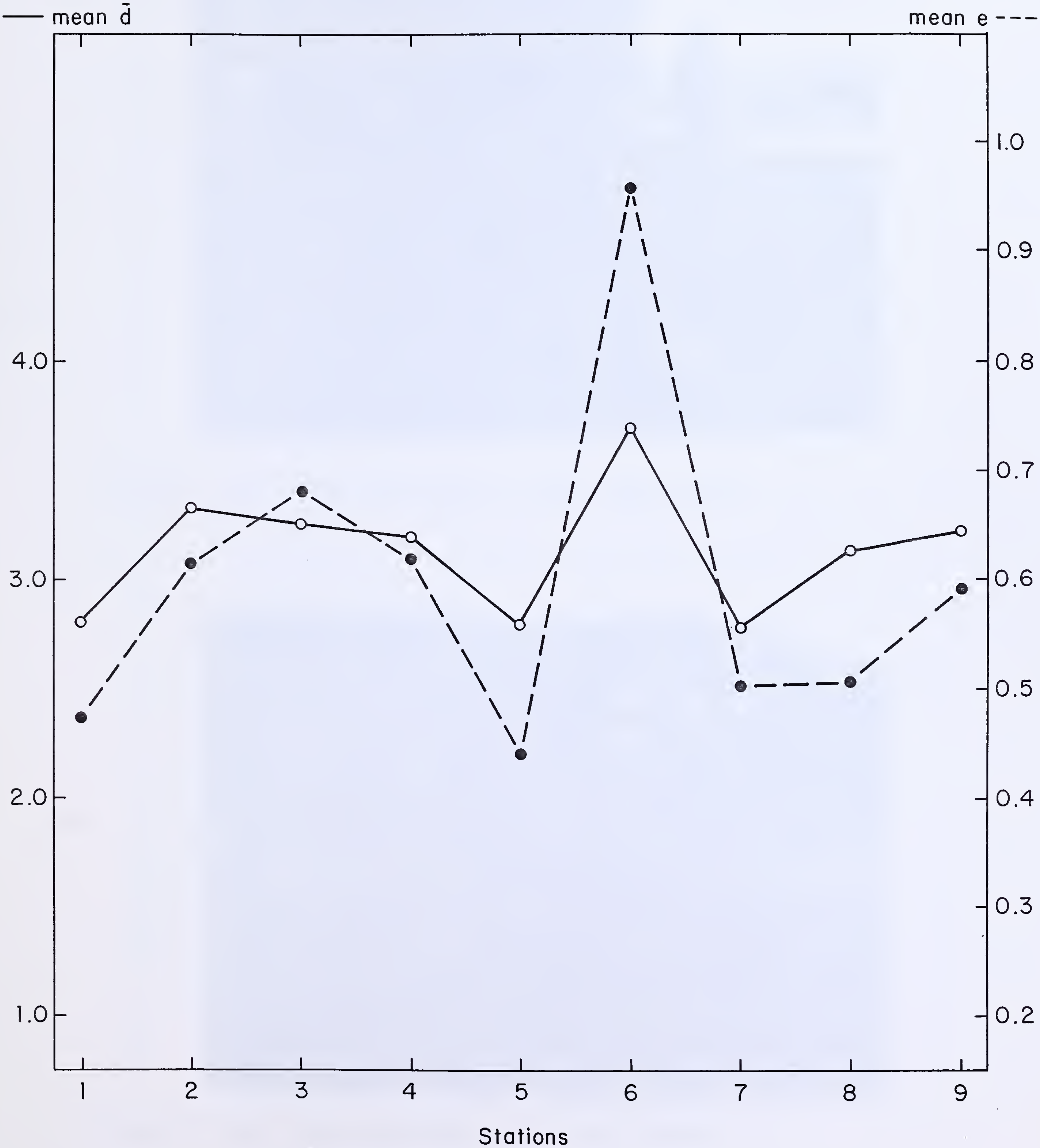
Figure 4. Belt Creek station No. 1, looking upstream

between 3 and 4 and e ranges between 0.6 and 0.8.

At station 2 (Figure 6) diversity and equitability rose to levels above 3.0 and 0.6, respectively. Also, the mean total number of organisms per sample declined slightly from the upstream control. Percent relative abundance of the major macroinvertebrate orders was well distributed with 67 percent of the organisms represented by stoneflies, mayflies, and caddis flies. The slight improvement over station 1 is most likely due to dilution and physical habitat. This sampling station is downstream from Otter Creek and the streambank riparian vegetation is relatively undisturbed.

Station 3 (Figure 7) downstream from Armington Coulee had the second lowest number of sub-ordinal taxa and mean taxa per sample (Table 4). The reduced number of kinds of organisms with no corresponding drop in $(\bar{d})$ and (e) is typical of chronically toxic situations.

Figure 5. Belt Creek Diversity ($\bar{d}$) and Equitability (e)



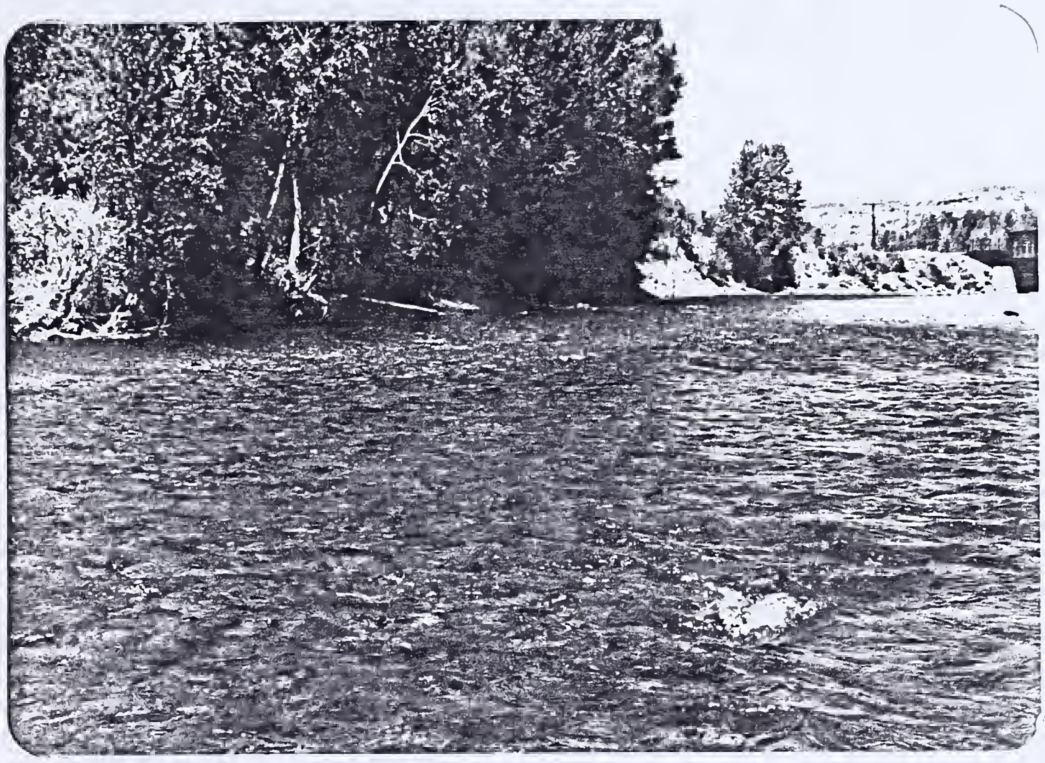


Figure 6. Belt Creek station No. 2, looking downstream

Figure 7. Belt Creek station No. 3, looking upstream

Table 4. Total sub-ordinal taxa collected per month and mean taxa per station per month collected, Belt Creek.

Station Numbers	July		August		November		Total taxa/
	Total/station	Mean of Samples	Total/station	Mean of Samples	Total/station	Mean of Samples	Taxa per sample
#1	21	17	23	20	25	22	29/20
#2	25	22	24	19	22	16	30/19
#3	20	17	20	17	22	18	24/17
#4	24	18	24	20	21	19	29/19
#5	22	17	23	20	25	18	31/18
#6	18	14	20	16	20	14	25/15
#7	23	18	23	18	17	15	28/17
#8	26	21	22	19	25	21	30/20
#9			20	17	25	20	26/19
Mean/Month	22	18	22	18	22	18	

Total numbers of organisms rose slightly at station 4 (Figure 8) to the highest observed during the study. This may be due to nutrient enrichment from residential development along the stream in this area. Although this situation was not confirmed from diversity and equitability values, it is very possible changes in these values are highly modified by the chronic toxicity problem that exists in the study area. This situation is partially applicable to station 5 (Figure 9) also, even though mean equitability was the lowest seen in the study. The reason this is noticeable at station 5 and not at station 4 is probably due to dilution from Neel Creek. Increased flow which diluted the toxics revealed drops in diversity and equitability that were previously masked.

Station 6 (Figure 10) at the town of Belt was the most severely distressed location sampled during the study (Figure 1; Tables 2, 3 and 4). Figure 4 shows artificially high $(\bar{d})$ and (e) values. This is due to the extreme depression in total number of invertebrates compared to the relatively small decline in number of sub-ordinate taxa or kinds. This is a classic situation encountered with toxic conditions and indicates the limits of statistical analysis.

Stations 7 and 8 (Figures 11 and 12) show gradual improvement in stream conditions as seen in Figures 3 and 4 and also Tables 1 through 4. The town of Belt seems to be the dividing point which separates the stream into two distinguishable zones. The downstream area shows a significantly higher percent relative abundance of caddis flies (Trichoptera) which generally can tolerate higher temperatures and sediment loads (Table 1).

Station 9, located just upstream from the confluence of Belt Creek with the Missouri River, had a diverse benthic population (Figures 3 and 4).

Figure 8. Belt Creek station No. 4, looking upstream

Figure 9. Belt Creek station No. 5, looking upstream

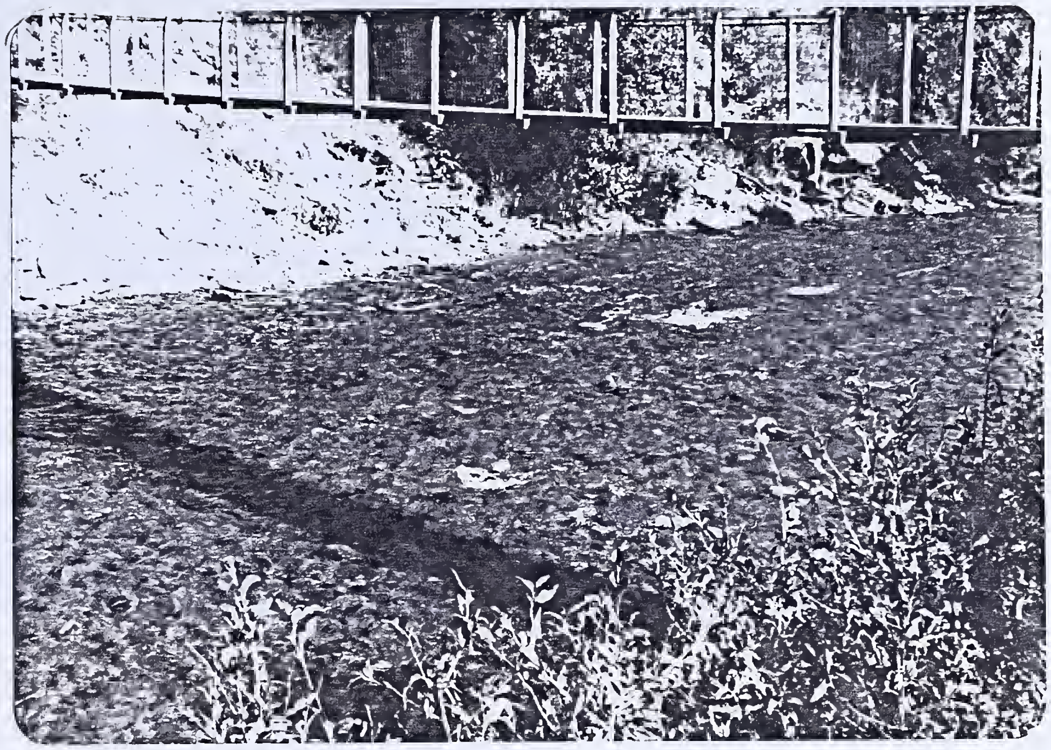


Figure 10. Belt Creek station No. 6, looking downstream

Generally, Belt Creek has a viable benthic population throughout the study area. Seasonal variations show the late fall (November) sampling period to be the time of the healthiest invertebrate populations. This is expected due to low water temperatures and decreased water useage. Higher dilutions and decreased temperatures substantially reduce toxic conditions.

Reclamation efforts in the Belt area could significantly improve the stream, but would have to be accompanied by reduction of nutrient inputs.

V. Results and discussion - Sand Coulee Creek

Benthic organisms were collected on the headwaters of Sand Coulee Creek and on its tributaries to determine the potential this stream would have if rehabilitation of the area were successful. Sampling was performed on Cottonwood Creek, Number Five Coulee, Sand Coulee at Centerville, and Sand Coulee at Tracy (when there was flow).

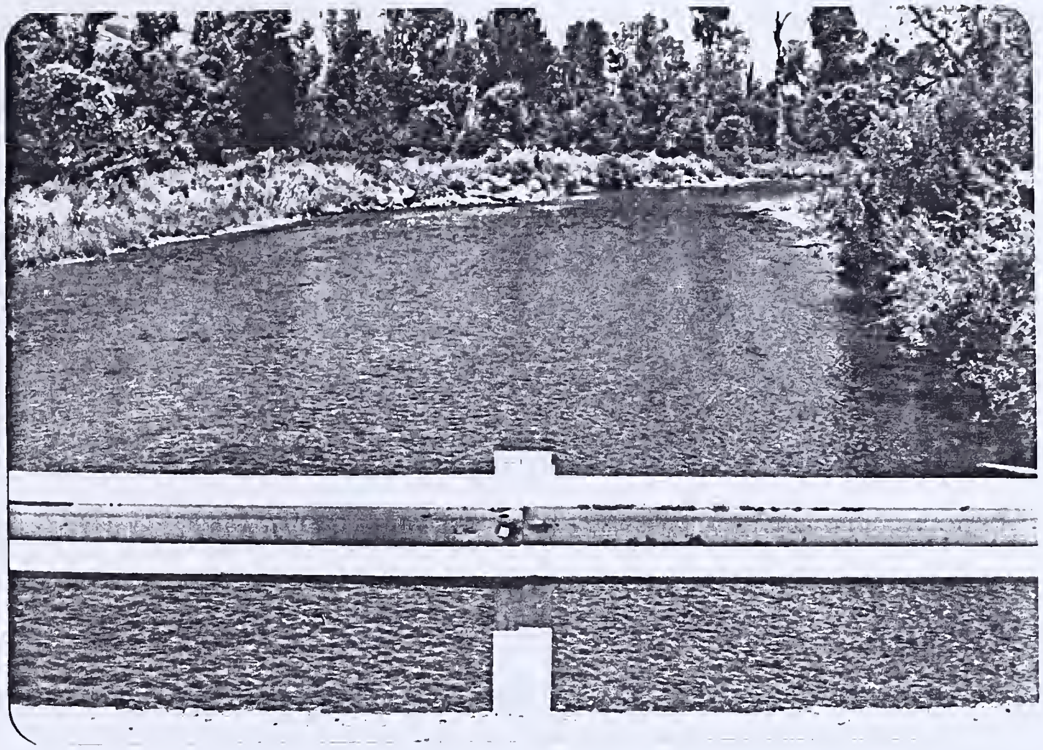


Figure 11. Belt Creek station No. 7, looking upstream

Figure 12. Belt Creek station No. 8, looking upstream

Problems were encountered in trying to use quantitative sampling techniques in this drainage due to reduced flows and the extent of man-caused disturbances throughout the basin. Therefore, multiple qualitative samples were collected at each station in various habitat types to give an approximation of the percent relative abundance of macroinvertebrates that would be available for recolonization of downstream portions of the drainage. Since the listing is brief and consistent with the headwaters upstream from Centerville, it is included in this section.

Diptera, or the true flies, make up the large majority of the biomass in this system. The genus Simulium (blackfly) is the most populus organisms in the drainage. The second most predominant organisms are the midges or family Chironomidae. Craneflies (Tipulidae) genus Tipula sp. and Dicranota sp. are also represented. Occasionally the family Empidae was encountered; Dipterans accounted for approximately 50 percent of the organisms present.

Other organisms identified regularly were Ephemeroptera (mayflies) of the genus Ephemerella sp., Bactis sp., and Stenonema sp.; Amphipoda (freshwater shrimp) genus Gammarus sp.; and Coleoptera (beetles) Ilybius sp.

Macroinvertebrates seen less frequently were: Plecoptera (stoneflies) Mnlerka sp.; Trichoptera (caddis flies), Parapsyche sp., Hydropsyche sp., Cheumatopsyche sp., and Hesperophylax sp., aquatic Collembola (springtails); and Hemoptera (true bugs) which are quite tolerant to pollution and not dependent on stream substrate for their existance. No other organisms were encountered during the study. If reclamation efforts were successful and water supply sufficient, a viable benthic community could repopulate downstream areas of the drainage through natural drift. Diversity in the

population would also be contributed from other drainages in the area over a period of time.

VI. Results and discussion - Missouri River

The sampling efforts on the Missouri River, although scheduled to be quantitative, were a qualitative measurement to assess impacts from Sand Coulee and Belt Creeks. Physical characteristics, including substrate, flow and vandalism, precluded quantitative sampling; replicate qualitative samples were taken seasonally.

The Missouri River at the mouth of Sand Coulee Creek had near zero velocity and the substrate was composed of fine sediment, clay and organic material. More than 90 percent of all macroinvertebrates recovered were midges (Chrionomidae) and there was no noticeable difference up or downstream from the mouth of Sand Coulee Creek. The lower section of this stream was dry for the entire study period. Invertebrates were very scarce at these two stations.

The Missouri River at Belt Creek had high current velocities, very large substrate size and large flow fluctuations which made conventional quantitative sampling ineffective. Qualitative sampling techniques indicated no significant difference in macroinvertebrate types observed between up and downstream sites. Over 70 percent of the benthos collected were caddis flies of the genuses Hydrophyche and Cheumatopsyche. The area is highly productive and invertebrates would total approximately 2,000 to 3,000 per square foot if quantitative samples could be successfully taken. Other invertebrates observed are identified in the appendix. Walleye pike eggs and fry were collected in benthic samples taken at Belt Creek Station No. 9. No degradation to the Missouri River caused by

Belt Creek was discerned during the course of this study.

VII. Conclusions

The Missouri River evidenced no detectable effects upon the macroinvertebrate populations that could be attributed to water received from either Sand Coulee or Belt Creeks during the study period. It is possible that effects might be detected during spring runoff, but doubtful, because of the high dilution factor provided by the river at this time of the year. Any future quantitative sampling should utilize artificial substrate samples, such as rock-filled basket types suspended off the river bottom and connected to the bank by a line or cable anchored at the high water mark. This procedure would eliminate much of the sampling difficulty encountered in this study.

Sand Coulee Creek did show viable benthic populations in the tributatires and upstream locations when surface flows existed. If the mine drainage problem were corrected, it is doubtful that the stream segment from the town of Tracy to its confluence with the Missouri River would be improved without the addition of significant volumes of water to the system. Further biological sampling of this drainage is probably not warranted.

Belt Creek from Otter Creek to its confluence with the Missouri River has a high potential for improvement. Although some detrimental influences were shown to be affecting invertebrates in the upstream portion of the study area, the greatest impacts were found from Neel Creek to the town of Belt. Mine reclamation efforts concentrated in this area could be very productive if sources of nutrients were identified and abatement was successful. The downstream segment did show good recovery, probably

due to dilution from tributary streams. Future sampling efforts should be expended to include the upstream portions of the drainage basin and tributaries that are suspected of adding significant amounts of pollution from either nutrients or heavy metals.

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IX. Appendix - Species list

Species	Missouri at Mouth of Belt Creek	Belt Creek #1											
		July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Plecoptera													
Claassenia sabulosa	X	2	-	2	1	1	-	4	2	1	1	-	1
Hesperoperla pacifica	X	3	1	2	2	13	9	6	9	5	3	2	3
Cultus sp.		-	-	-		-	-	-		-	-	-	
Isogenoides sp.		-	-	-		-	-	-		-	-	-	
Chloroperlinae	X	26	10	24	20	29	38	23	30	8	15	8	10
Pteronarcys californica		-	-	1	1	2	1	-	1	1	-	-	1
Diura sp.		-	-	-		-	-	-		-	-	-	
Skwala sp.		-	-	-		-	-	1	1	-	-	-	
Pteronarcella badia	X	9	3	4	5	10	8	9	9	4	4	2	3
Isoperla sp.	X	37	23	17	26	8	2	4	5	1	2	1	1
Ephemeroptera													
Baetis sp.	X	79	62	93	78	116	77	99	97	8	18	9	12
Pseudocleon sp.	X	18	17	20	18	16	28	9	18	7	5	4	5
Tricorythodes sp.	X	-	-	-		-	-	-		-	-	-	
Rhithrogena sp.	X	-	-	-		-	-	-		-	-	-	
Ephemerella sp.	X	9	8	4	7	12	5	2	6	1	2	3	2
Heptagenia sp.	X	-	-	-		-	-	-		2	3	5	3
Paraleptophlebia sp.	X	-	-	-		-	-	-		-	1	1	1

IX. Appendix - Species list (Cont.)

Species	Missouri at Mouth of Belt Creek	Belt Creek #1											
		July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera													
Arctopsyche sp.	X	-	-	-		1	-	-	1	-	-	-	
Hydropsyche sp.	X	2	1	3	2	168	131	186	162	6	14	7	9
Parapsyche sp.		-	-	-		-	-	-		-	-	-	
Cheumatopsyche sp.	X	30	22	44	32	31	26	21	26	31	38	20	30
Micrasema sp.		-	-	2	1	-	-	-		-	-	-	
Brachycentrus sp.	X	41	16	25	27	2	3	2	2	3	3	1	2
Helicopsyche sp.		1	-	-	1	-	-	-		-	2	1	1
Oecetis sp.	X	-	-	-		-	-	-		1	4	3	3
Hydroptila sp.		-	-	1	1	-	-	-		-	-	-	
Rhyacophila sp.	X	-	-	-		-	-	-		-	-	-	
Glossosoma sp.		-	-	-		-	-	-		-	-	-	
Lepidostoma sp.	X	28	19	8	18	6	4	10	7	3	9	8	7
Coleoptera													
Optioservus sp.	X	1	-	-	1	-	1	3	1	2	4	3	3
Zaitzevia sp.		-	-	-		-	2	1	1	-	1	1	1
Heterlimnius sp.	X	2	1	2	2	5	5	2	4	2	11	4	6
Diptera													
Atherix sp.		2	1	1	2	2	3	2	2	2	3	1	2
Tipula sp.		-	-	-		-	-	-		-	-	-	
Hexatoma sp.		-	-	-		1	1	1	1	-	1	-	1

IX. Appendix - Species list (Cont.)

Species	Missouri at Mouth of Belt Creek	Belt Creek #1											
		July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)													
Simulium sp.	X	2	9	8	6	11	3	4	6	3	2	3	3
Chironomidae	X	19	89	105	71	70	100	181	117	25	47	29	34
Ondonata													
Ophiogomphus sp.		-	-	-		-	-	-		-	-	-	
Lepidoptera													
Paragyractis sp.		-	-	-		-	-	-		-	-	-	
Hirundinea		-	-	-		-	-	-		-	-	-	
Hydracarina		-	-	-		-	-	1	1	1	-	-	1

IX. Appendix - Species list

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
	Belt Creek #2											
Plecoptera												
Claassenia sabulosa	1	1	-	1	-	1	2	1	2	-	-	1
Hesperoperla pacifica	2	3	1	2	10	2	9	7	4	6	7	6
Cultus sp.	-	-	-		-	-	-		-	-	-	
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	12	4	8	8	5	4	4	4	2	11	2	5
Pteronarcys californica	2	2	3	2	3	-	2	2	2	-	1	1
Diura	-	-	-		-	-	-		-	-	-	
Skwala sp.	-	-	-		-	-	1	1	-	-	-	
Pteronarcella badia	31	38	29	33	16	8	8	11	2	1	3	2
Isoperla sp.	26	12	18	19	3	2	-	2	2	9	-	4
Ephemeroptera												
Baetis sp.	28	35	21	28	17	20	11	16	7	6	4	6
Pseudocleon sp.	10	4	11	8	5	2	1	3	2	3	1	2
Tricorythodes sp.	-	-	-	-	-	-	-		-	-	1	1
Rhithrogena sp.	1	-	-	1	-	-	-		-	-	-	
Ephemerella sp.	8	15	7	10	3	2	5	3	4	4	3	4
Heptagenia sp.	-	-	-		-	-	-		-	1	4	2
Paraleptophlebia sp.	-	-	-		-	2	-	1	-	-	1	1

IX. Appendix - Species list (Cont.)

Species		July		$\overline{X}$		August		$\overline{X}$		November		$\overline{X}$
	Belt Creek #2											
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	-		-	-	-	
Hydropsyche sp.	2	-	2	1	57	48	162	89	8	4	3	5
Parapsyche sp.	-	-	-		-	-	-		-	-	-	
Cheumatopsyche sp.	25	41	27	31	14	10	98	41	24	16	9	16
Micrasema sp.	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	19	35	8	21	2	-	-	1	-	2	-	1
Helicopsyche sp.	2	1	3	2	2	-	-	1	-	-	-	
Oecetis sp.	-	-	1	1	2	1	-	1	-	2	1	1
Hydroptila sp.	-	-	-		-	-	-		-	-	-	
Rhyacophila sp.	1	1	-	1	-	-	-		-	-	-	
Glossosoma sp.	-	1	1	1	-	-	-		-	-	-	
Lepidostoma sp.	4	9	12	8	2	-	-	1	-	1	-	1
Coleoptera												
Optioservus sp.	1	2	1	2	2	4	3	3	3	5	1	3
Zaitzevia sp.	-	-	-		3	1	3	2	-	-	-	
Heterlimnius sp.	2	5	2	3	4	1	2	2	1	-	-	1
Diptera												
Atherix sp.	-	2	1	1	1	3	4	2	3	4	2	3
Tipula sp.	-	-	-		-	-	-		-	-	-	
Hexatoma sp.	-	1	1	1	-	1	1	1	-	-	-	

IX. Appendix - Species list (Cont.)

Species		Belt Creek #2										
	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	9	14	3	9	3	-	12	5	-	-	1	1
Chironomidae	39	60	51	50	83	72	144	100	22	52	11	28
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	-	-		-	-	-		-	-	-	
Hydracarina	1	1	2	1	-	-	-		-	-	-	

IX. Appendix - Species list

	Belt Creek #3											
Species		July		$\overline{X}$		August		$\overline{X}$		November		$\overline{X}$
Plecoptera												
Claassenia sabulosa	1	4	2	2	-	-	3	1	-	-	3	1
Hesperoperla pacifica	3	1	1	2	3	1	4	3	2	1	2	2
Cultus sp.	-	-	-		-	-	-		-	-	-	
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	6	10	7	8	4	18	23	15	8	11	13	11
Pteronarcys californica	1	1	1	1	-	-	-		3	-	-	1
Diura sp.	-	-	-		-	-	-		-	-	-	
Skwala sp.	-	-	-		-	-	1	1	-	-	-	
Pteronarcella badia	11	8	14	11	4	17	6	9	6	2	1	3
Isoperla sp.	5	3	17	8	9	3	19	10	22	12	29	21
Ephemeroptera												
Baetis sp.	31	62	73	55	95	115	130	113	21	50	30	34
Pseudocleon sp.	9	8	13	10	4	16	9	10	2	17	4	8
Tricorythodes sp.	-	-	-		-	-	-		-	-	-	
Rhithrogena sp.	-	-	-		-	-	-		2	4	5	4
Ephemerella sp.	5	7	7	6	3	8	4	5	3	8	27	13
Heptagenia sp.	-	1	-	1	-	-	-		-	3	3	2
Paraleptophlebia sp.	-	-	-		-	-	-		-	-	-	

IX. Appendix - Species list (Cont.)

Belt Creek #3

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	-		-	-	-	
Hydropsyche sp.	1	1	-	1	41	73	85	66	37	44	51	44
Parapsyche sp.	-	-	-		-	-	-		-	-	-	
Cheumatopsyche sp.	2	4	1	2	14	23	60	32	8	20	9	12
Micrasema sp	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	32	27	3	21	2	1	4	2	-	2	-	1
Helicopsyche sp.	1	-	-	1	-	2	1	1	-	-	-	
Oecetis sp.	-	-	-		-	-	-		-	-	-	
Hydroptila sp.	-	-	-		-	-	-		-	-	-	
Rhyacophila sp.	-	-	-		-	-	-		-	-	-	
Glossosoma sp.	-	-	-		-	-	-		-	-	-	
Lepidostoma sp.	-	1	6	2	2	5	8	5	6	2	8	5
Coleoptera												
Optioservus sp.	1	-	-	1	-	1	2	1	1	4	2	2
Zaitzevin sp.	-	-	-		-	-	-		-	-	-	
Heterlimnius sp.	6	9	5	7	2	3	2	2	3	2	2	2
Diptera												
Atherix sp.	-	-	-		2	-	1	1	-	1	-	1
Tipula sp.	-	-	-		-	-	-		-	-	-	-
Hexatoma sp.	2	1	5	3	5	2	4	4	1	2	1	1

IX. Appendix - Species list (Cont.)

Species	Belt Creek #3											
	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	5	14	23	14	-	-	4	1	15	41	22	26
Chironomidae	22	34	16	24	68	39	55	54	20	43	16	26
Odonata												
Ophiogomphus sp.	-	-	-		-	-	-		-	-	-	
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	-	-		-	-	-		-	-	1	1
Hydracarina	-	-	-		-	-	-		-	-	-	

IX. Appendix - Species List

Belt Creek #4

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Plecoptera												
Claassenia sabulosa	2	2	-	1	3	4	1	3	1	3	-	1
Hesperoperla pacifica	-	3	1	1	2	11	1	5	7	4	12	8
Cultus sp.	-	-	-		-	-	-	-	-	-	-	-
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	2	4	6	4	15	19	3	12	4	3	3	3
Pteronarcys californica	-	2	-	1	-	-	-		-	-	-	
Diura sp.	-	-	-		1	-	-	1	-	-	-	
Skwala sp.	-	1	-	1	-	-	-		-	-	-	
Pteronarcella badia	18	10	8	12	7	13	15	12	8	9	5	7
Isoperla sp.	2	5	8	5	12	21	4	12	1	8	13	7
Ephemeroptera												
Baetis sp.	33	41	15	30	61	104	90	85	3	6	2	4
Pseudocleon sp.	6	11	2	6	10	24	8	14	-	5	6	4
Tricorythodes sp.	-	-	-		-	-	-		-	-	-	
Rhithrogena sp.	-	-	-		-	2	-	1	2	1	1	1
Ephemerella sp.	7	12	9	9	17	26	7	17	3	15	9	9
Heptagenia sp.	-	-	-		2	4	-	2	-	-	-	
Paraleptophlebia sp.	-	-	2	1	-	-	-		-	1	-	1

IX. Appendix - Species list (Cont.)

Belt Creek #4

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	-		-	-	-	
Hydropsyche sp.	2	2	1	2	126	179	212	172	20	17	34	24
Parapsyche sp.	-	-	-		-	-	-		-	-	-	
Cheumatopsyche sp.	-	8	-	3	14	28	91	44	149	79	102	110
Micrasema sp.	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	1	9	5	5	3	14	-	6	1	1	2	3
Heliocopsyche sp.	-	-	-		-	-	-		-	-	-	
Oecetis sp.	-	-	-		-	-	-		1	-	1	1
Hydroptila sp.	-	-	-		-	-	-		-	-	-	
Rhyacophila sp.	-	-	-		-	-	-		-	-	-	
Glossosoma sp.	1	-	-	1	-	-	-		-	-	-	
Lepidostoma sp.	2	4	1	2	16	17	1	8	2	3	7	4
Coleoptera												
Optioservus sp.	2	1	6	3	8	18	4	10	23	12	37	24
Zaitzevia sp.	-	-	2	1	-	2	-	1	-	-	-	
Heterlimnius sp.	-	2	3	2	1	5	2	3	17	12	25	18
Diptera												
Atherix sp.	1	2	4	2	2	2	2	2	1	2	2	2
Tipula	-	-	-		-	-	-		-	-	-	
Hexatoma sp.	2	1	3	2	3	4	1	3	2	3	2	2

IX. Appendix - Species list (Cont.)

	Belt Creek #4											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	44	71	12	42	9	2	1	4	2	3	6	4
Chironomidae	96	124	156	125	189	111	66	122	33	41	24	33
Odonata												
Ophiogomphus sp.	-	-	1	1	-	1	-	1	-	-	-	
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	-	-		-	-	-		-	-	-	
Hydracarina	-	-	-		-	1	-	1	-	-	-	

IX. Appendix - Species list

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
	Belt Creek #5											
Plecoptera												
Claassenia sabulosa	-	1	-	1	-	1	2	1	-	2	-	1
Hesperoperla pacifica	-	-	-		5	9	7	7	3	5	1	3
Cultus sp.	-	-	-		-	-	-		-	-	-	
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	4	10	16	10	14	9	8 8	10	5	11	13	6
Peteronarcys californica	-	-	1	1	2	1	1	1	-	-	-	
Diura sp.	-	-	-		-	-	-		-	-	-	
Skwala sp.	-	-	-		1	1	-	1	-	1	-	1
Pteronarcella badia	3	2	6	4	7	6	13	9	6	10	2	6
Isoperla sp.	-	-	5	2	1	2	2	2	2	4	1	2
Ephemeroptera												
Baetis sp.	38	28	45	37	91	63	81	78	2	4	2	3
Pseudocleon sp.	5	6	4	5	15	7	18	13	1	-	1	1
Tricorythodes sp.	-	-	-		-	-	-		-	-	-	
Rhitrogena sp.	-	-	-		-	-	-		-	7	1	3
Ephemerella sp.	6	11	19	12	10	22	30	21	3	2	9	5
Heptagenia sp.	-	-	-		-	-	-		2	2	3	2
Paraleptophlebia sp.	-	-	-		-	-	-		-	3	13	5

IX. Appendix - Species list (Cont.)

	Belt Creek #5											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	1	1	-	1	-	1
Hydropsyche sp.	3	8	2	4	63	80	107	83	6	4	3	4
Parapsyche sp.	-	-	-		-	-	1	1	-	-	-	
Cheumatopsyche sp.	4	1	12	6	28	21	37	29	2	1	-	1
Micrasema sp.	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	2	5	6	4	1	4	5	3	-	-	-	
Helicopsyche sp.	8	2	4	5	-	-	-		-	-	1	1
Oecetis sp.	1	-	-	1	1	-	-	1	-	-	-	
Hydroptila sp.	2	-	-	1	-	-	-		-	-	-	
Rhyacophila sp.	-	-	-		-	-	-		-	-	-	
Glossosoma sp.	-	-	-		-	-	-		-	-	-	
Lepidostoma sp.	6	14	8	9	5	3	2	3	-	2	1	1
Coleoptera												
Optioservus sp.	2	1	2	2	8	6	2	5	9	23	29	20
Zaitzevia sp.	-	-	-		4	7	4	5	-	2	-	1
Heterlimnius sp.	-	2	4	2	4	3	1	3	-	2	-	1
Diptera												
Atherix sp.	-	1	1	1	1	4	2	2	-	4	1	2
Tipula sp.	-	-	1	1	-	-	-		-	-	-	
Hexatoma sp.	4	2	2	3	2	3	5	3	-	1	-	1

IX. Appendix - Species list (Cont.)

	Belt Creek #5											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	12	8	5	8	-	-	-		57	40	25	41
Chironomidae	217	290	341	283	85	53	155	98	10	8	2	7
Odonata												
Ophiogomphus sp.	-	-	-		-	-	-		-	1	-	1
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	-	-		-	-	-		-	-	-	
Hydracarina	-	-	-		-	-	-		-	-	-	

IX. Appendix - Species list

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
					Belt Creek #6							
Plecoptera												
Claassenia sabulosa	2	1	-	1	-	-	1	1	-	-	-	
Hesperoperla pacifica	1	-	2	1	-	2	1	1	1	1	-	1
Cultus sp.	-	-	-		-	-	-		-	-	-	
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	6	9	13	9	8	9	15	11	12	7	9	9
Pteronarcys californica	-	-	-		-	-	-		-	-	-	
Diura sp.	-	-	-		-	-	-		-	-	-	
Skwala sp.	-	-	-		-	-	-		-	-	-	
Pteronarcella badia	8	4	5	6	-	2	1	1	1	2	1	1
Isoperla sp.	-	1	-	1	-	-	-		-	-	-	
Ephemeroptera												
Baetis sp.	5	7	22	11	2	9	1	4	1	1	2	1
Pseudocleon sp.	1	-	1	1	-	1	-	1	-	-	-	
Tricorythodes sp.	-	-	-		-	-	-		-	-	-	
Rhithrogena sp.	-	-	-		1	1	-	1	2	-	-	1
Ephemerella sp.	-	2	4	2	1	1	-	1	2	-	1	4
Heptagenia sp.	-	-	-		-	1	2	1	2	1	-	1
Paraleptophlebia sp.	-	2	1	1	2	-	-	1	-	-	3	1

IX. Appendix - Species list (Cont.)

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	-		-	-	-	
Hydropysche sp.	3	-	-	1	3	4	7	5	-	1	-	1
Parapsyche sp.	-	-	-		-	-	-		-	-	-	
Cheumatopysche sp.	41	19	10	23	4	5	4	4	-	-	-	
Micrasema sp.	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	28	18	11	19	2	4	6	4	1	2	-	1
Helicopsyche sp.	-	-	-		-	-	-		-	-	2	1
Oecetis sp.	-	-	-		-	-	-		3	1	1	2
Hydroptila sp.	-	-	-		-	-	-		-	-	-	
Rhyacophila	-	-	-		-	-	-		-	-	-	
Glossosoma sp.	-	-	-		-	-	-		-	-	-	
Lepidostoma sp.	6	21	11	13	2	4	2	3	3	4	5	4
Coleoptera												
Optioservus sp.	5	4	2	4	3	2	2	2	7	15	5	9
Zaitzevia sp.	-	-	-		-	-	-		-	-	-	
Heterlimnius sp.	-	-	1	1	3	2	1	2	-	-	-	
Diptera												
Atherix sp.	-	-	-		1	1	1	1	1	2	1	1
Tipula sp.	-	-	-		-	-	-		-	-	-	
Hexatoma sp.	1	1	3	2	11	9	3	8	2	5	2	3

IX. Appendix - Species list (Cont.)

	Belt Creek #6											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	10	8	5	8	2	2	1	2	4	1	1	2
Chironomidae	8	18	13	13	20	11	6	12	1	1	-	1
Odonata												
Ophiogomphus sp.	-	-	-		-	-	-		1	-	-	1
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	-	-		-	-	-		-	-	-	
Hydracarina	-	-	-		-	-	-		1	-	-	1

IX. Appendix - Species list

	Belt Creek #7											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Plecoptera												
Claassenia sabulosa	2	1	-	1	1	-	-	1	-	-	-	
Hesperoperla pacifica	-	-	1	1	2	1	1	1	3	1	1	2
Cultus sp.	-	-	-		-	-	-		-	-	-	-
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	1	2	-	1	-	2	1	1	3	2	3	3
Pteronarcys californica	-	-	1	1	-	-	-		-	-	-	
Diura sp.	-	1	-	1	-	-	-		-	-	-	
Skwala sp.	-	-	-		-	1	-	1	-	-	-	
Pteronarcella badia	12	3	8	8	13	6	21	13	17	8	3	9
Isoperla sp.	1	6	2	3	-	-	-	-	1	-	-	1
Ephemeroptera												
Baetis sp.	85	67	50	67	28	19	16	18	8	20	11	13
Pseudocleon sp.	8	5	9	7	2	2	1	2	-	-	-	-
Tricorythodes sp.	-	1	-	1	-	-	-		-	-	-	
Rhithrogena sp.	1	2	1	1	2	1	4	2	2	4	9	5
Ephemerella sp.	18	7	12	12	2	4	2	3	25	41	72	46
Heptagenia sp.	1	2	1	1	2	-	4	2	3	1	-	1
Paraleptophlebia sp.	2	1	-	1	-	1	-	1	-	-	-	

IX. Appendix - Species list (Cont.)

	Belt Creek #7											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	-		-	-	-	
Hydropsyche sp.	2	5	2	3	181	92	84	119	278	88	40	135
Parapsyche sp.	-	-	-		-	-	-		-	-	-	
Cheumatopsyche sp.	-	-	-		43	23	27	31	331	157	102	197
Micrasema sp.	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	14	4	6	8	1	3	10	5	9	2	2	4
Helicopsyche sp.	-	-	-		-	-	-		-	-	-	
Oecetis sp.	-	-	-		-	-	1	1	-	-	-	
Hydroptila sp.	-	-	-		-	-	-		-	-	-	
Rhyacophila sp.	-	-	-		-	-	-		-	-	-	
Glossosoma sp.	-	-	-		-	1	-	1	-	-	-	
Lepidostoma sp.	-	-	-		-	-	-		-	-	-	
Coleoptera												
Optioservus sp.	4	2	3	3	2	9	20	10	27	21	13	20
Zaitzevia sp.	-	-	-		-	1	2	1	-	-	-	
Heterlimnius sp.	3	1	3	2	2	2	2	2	2	2	-	1
Diptera												
Atherix sp.	1	-	1	1	1	3	-	1	5	3	1	3
Tipula	-	-	-		-	-	-		-	-	-	
Hexatoma sp.	3	4	2	3	2	3	5	3	4	1	2	2

IX. Appendix - Species list (Cont.)

	Belt Creek #7											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	22	26	30	26	14	8	10	11	-	-	-	
Chironomidae	11	22	23	19	25	19	31	25	16	9	10	12
Odonata												
Ophiogomphus sp.	-	-	-		-	-	-		-	-	-	
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	-	-		-	-	-		-	-	-	
Hydracarina	-	1	-	1	-	-	-		1	-	-	1

IX. Appendix - Species list

Belt Creek #8

Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Plecoptera												
Claassenia sabulosa	2	1	1	1	-	-	-		-	-	-	
Hesperoperla pacifica	1	-	-	1	2	1	1	1	-	1	-	1
Cultus sp.	-	-	-		-	-	-		-	-	-	
Isogenoides sp.	-	-	-		-	-	-		-	-	-	
Chloroperlinae	1	-	1	1	1	4	3	3	15	22	9	15
Pteronarcys californica	1	-	-	1	-	1	-	1	1	-	-	1
Diura sp.	2	3	2	2	-	-	-		-	-	-	
Skwala sp.	-	-	-		-	3	1	1	-	1	-	1
Pteronarcella badia	9	5	6	7	9	4	5	6	3	2	1	2
Isoperla sp.	7	2	1	3	-	-	-		-	-	-	
Ephemeroptera												
Baetis sp.	58	71	49	59	16	26	18	20	13	6	2	7
Pseudocleon sp.	4	2	8	5	-	-	-		-	2	6	3
Tricorythodes sp.	-	1	3	1	-	-	-		4	3	1	3
Rhithrogena sp.	-	-	-		-	-	-		12	7	3	7
Ephemerella sp.	-	2	1	1	6	2	1	3	37	51	23	37
Heptagenia sp.	5	15	23	14	4	8	2	5	2	1	-	1
Paraleptophlebia sp.	-	2	-	1	-	2	4	2	14	10	9	11

IX. Appendix - Species list (Cont.)

	Belt Creek #8											
Species	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Trichoptera												
Arctopsyche sp.	-	-	-		-	-	-		-	-	-	
Hydropsyche sp.	74	101	81	85	118	89	61	89	143	160	79	127
Parapsyche sp.	-	-	-		-	-	-		-	-	-	
Cheumatopsyche sp.	28	31	12	24	8	19	4	10	33	40	16	30
Micrasema sp.	-	-	-		-	-	-		-	-	-	
Brachycentrus sp.	19	16	28	21	12	20	10	14	1	6	2	3
Heliocopsyche sp.	2	1	2	2	-	-	-		-	1	-	1
Oecetis sp.	-	1	-	1	9	5	6	7	2	4	3	3
Hydroptila sp.	-	-	-		-	-	-		-	-	-	
Rhyacophila sp.	-	-	-		-	-	-		-	-	-	
Glossosoma sp.	-	-	-		-	-	-		-	-	-	
Lepidostoma sp.	-	-	-		-	-	-		-	-	-	
Coleoptera												
Optioservus sp.	9	14	6	10	8	4	2	5	3	4	2	3
Zaitzevia sp.	3	2	1	2	-	1	-	1	1	2	1	1
Heterlimnius sp.	1	-	-	1	6	3	2	4	3	2	4	3
Diptera												
Atherix sp.	-	-	-		1	2	1	1	1	3	2	2
Tipula sp.	-	-	-		-	-	-		-	-	-	
Hexatoma sp.	4	1	3	3	2	2	3	2	1	1	3	2

IX. Appendix - Species list (Cont.)

Species	Belt Creek #8											
	July			$\overline{X}$	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)												
Simulium sp.	41	23	10	25	1	3	-	1	11	8	6	8
Chironomidae	25	58	45	43	11	10	3	8	16	26	8	17
Odonata												
Ophiogomphus sp.	-	-	-		1	-	1	1	-	-	-	
Lepidoptera												
Paragyractis sp.	-	-	-		-	-	-		-	-	-	
Hirundinea	-	1	-	1	-	-	-		1	1	-	1
Hydracarina	-	1	1	1	-	1	-	1	-	-	-	

IX. Appendix - Species list

Species	August			$\overline{X}$	November			$\overline{X}$
				Belt Creek #9				
Plecoptera								
Claassenia sabulosa	4	6	9	6	3	5	2	3
Hesperoperla pacifica	2	2	3	2	-	-	1	1
Cultus sp.	2	-	1	1	1	-	-	1
Isogenoides sp.	-	-	-		-	-	1	1
Chloroperlinae	-	-	-		-	-	1	1
Pteronarcys californica	-	-	-		-	-	-	
Diura sp.	-	-	-		-	-	-	
Skwala sp.	-	-	-		-	-	-	
Pteronarcella badia	-	-	-		-	-	-	
Isoperla sp.	-	-	-		-	-	-	
Ephemeroptera								
Baetis sp.	34	22	19	25	29	35	30	31
Pseudocleon sp.	6	-	2	3	4	6	3	4
Tricorythodes sp.	15	9	8	11	12	2	20	11
Rhithrogena sp.	9	2	8	6	55	29	44	43
Ephemerella sp.	1	-	-	1	47	33	68	49
Heptagenia sp.	-	2	1	1	6	2	3	4
Paraleptophlebia sp.	3	4	-	2	19	42	76	46

IX. Appendix - Species list (Cont.)

Species		August		$\overline{X}$		November		$\overline{X}$
				Belt Creek #9				
Trichoptera								
Arctopsyche sp.	-	-	-		-	-	-	
Hydropsyche sp.	67	91	180	115	20	11	6	12
Parapsyche sp.	-	-	-		-	-	-	
Cheumatopsyche sp.	22	17	45	28	105	73	87	88
Micrasema sp.	-	-	-		-	-	-	
Brachycentrus sp.	4	4	11	6	4	1	2	2
Helicopsyche sp.	3	4	2	3	61	14	8	28
Oecetis sp.	1	2	5	3	35	6	13	18
Hydroptila sp.	-	-	-		-	1	-	1
Rhyacophila sp.	-	-	-		-	-	1	1
Glossosoma sp.	-	-	-		-	-	-	
Lepidostoma sp.	-	-	-		-	-	-	
Coleoptera								
Optioservus sp.	11	6	5	7	3	1	2	2
Zaitzevia sp.	-	-	-		2	1	2	2
Heterlimnius sp.	-	-	-		2	-	-	1
Diptera								
Atherix sp.	-	-	-		-	-	-	
Tipula sp.	-	-	-		-	-	-	
Hexatoma sp.	3	4	3	3	2	1	1	1

IX. Appendix - Species list (Cont.)

	Belt Creek #9							
Species	August			$\overline{X}$	November			$\overline{X}$
Diptera (Cont.)								
Simulium sp.	1	12	-	4	15	117	4	45
Chironomidae	43	24	68	45	10	4	5	6
Odonata								
Ophiogomphys sp.	-	-	-		-	-	-	
Lepidoptera								
Paragyractis sp.	-	1	-	1	-	-	-	
Hirundinea	-	-	-		-	-	-	
Hydracarina	-	-	-		-	-	-	

SOILS AND VEGETATION TECHNICAL INVESTIGATION

BELT AND SAND COULEE AREAS
CASCADE COUNTY, MONTANA

2. Soils and vegetation technical investigation

Contents

Contents (Cont.)

Tables

I. Introduction

Past coal mining activities in the Belt-Sand Coulee areas have resulted in serious impacts on soil and vegetation resources. Mine wastes, open adits, relict structures and other debris have resulted in disturbed areas that are not capable of supporting stable ecological communities. Mine effluent high in acidity exists at some sites rendering areas barren of vegetative growth.

A soil and vegetation investigation was conducted in the area during 1980-1981 to determine environmental impacts to the area and to identify mitigative measures for those existing problems. A literature review was prepared and field inventories were conducted to qualitatively and quantitatively describe the soils/vegetation community.

II. Soils

A. Literature review

A literature review was conducted to determine current state of the art reclamation procedures for soils affected by acid mine drainage and heavy metals toxicity.

Geidel (1979) describes the formation of acid mine drainage:

> The suite of iron sulfide minerals (FeS-FeS_2), commonly occurring as marcosite, tiolite, or pyrite in the coal and overlying strata oxidize upon exposure to the atmosphere and a humid environment to form hazardous iron sulfates. These compounds commonly appear as white and yellow salt crusts on weathered rock surfaces. Natural waters flowing over the weathered surfaces readily dissolve these salts which hydrolize in water to form acidic, high sulfate, and high iron drainages. The iron, initially present in the ferrous state oxidizes to ferric iron with an additional release of acidity .

Caruccio (1968) demonstrated that the degree of acidity depends on:

(1) the calcium carbonate content of the strata;

(2) the pH of the groundwater;

(3) the mode of occurrence of the iron disulfide; and

(4) the neutralizing and buffering capacity of the groundwater.

The degree of acidity associated with any mine effluent is a result of the potential of acid and alkaline production, which are time-dependent and solubility-dependent, respectively.

Acid formation is a continuous process which takes place in the micro-environments of chemical reactivity left after a period of water percolation. Such microenvironments are composed of micropores in the geochemical system which display sufficient capillary force to hold water against the downward force of gravity. As long as oxygen is available, weathering products (hydrous iron sulphates) are formed which continue to accumulate until a new wetting front removes them; this action is followed by additional accumulations of acid-forming products as the cycle begins again. Arrest of the oxidation reaction will eventually result when the solubility limit is reached; that limit is many times greater in magnitude than the restrictive limit associated with alkalinity production. This results in an increase in concentrations of acidity over time (Geidel, 1979).

As acidity increases with time, the rate of reactivity and subsequent formation of alkalinity decreases with time. This geochemical process is a result of the solubility limit of calcium carbonate in water, which is reached during the initial chemical reactions. Resultant additional contact with calcium carbonate does not significantly increase the alkalinity of the system.

The period between water flushings in such a system is critical. Continual flushings prevent the accumulations of oxidation products, resulting in less severe acidic effluent which may be neutralized by available alkalinity, unless the source of acidity outlasts the source of alkalinity. Acidity of great strength results from infrequent flushings and overwhelms the available alkalinity.

In the absence of calcareous material or in a geochemical system of infrequent flushings, as outlined above, resultant pH can be less than 5.5. This contributes to the survival of iron bacteria which promote acid production by oxidation of ferrous to ferric iron. Low pH further increases the solubility of iron which reacts with pyrite and increases acidic production. More iron is then placed in solution and the system becomes self-propagating.

Position of calcareous material is also a factor in drainage quality. If the drainage waters flow through calcium carbonates before coming into contact with pyrites, then some alkalinity is developed which may effectively or partially neutralize the acidity.

The textural integrity (pyrite morphology) of the types of pyrites in a geochemical system is also important in the resultant drainage quality. Pyrite present in coal and associated strata occurs in five forms: 1) mossy-pitted; 2) euhedral grains; 3) massive, plant replacements; 4) cleat coats; and 5) framboidal. The latter is the most reactive as a result of its great surface area caused by its fine granularity.

Other factors which influence mine drainage quality are the dissolution of clay minerals and the cation exchange capacity (CEC) of the overburden. Geidel (1976) found that shales collected from eastern Kentucky and West Virginia exhibited dissolution of aluminum silicate minerals during the

weathering of clays which liberated hydroxide. This reaction increased available alkalinity and subsequently acted as an acid neutralizer. The cation exchange capacity proved to be an important neutralizing factor when the stripped overburden was dominated by shales. Surface and interlayer cations of the associated clay minerals could exchange with cations in acid water drainage. Although ion retention in the exchangeable position is transitory, this process serves to neutralize acidity during these times when the hydrogen ions penetrate the clay's crystaline lattice and subsequently exchange sites with metal cations.

The acid conditions generated by tailings or slag piles upset physical and chemical equilibrium of the underlying soils. This results in a barren, sterile landscape adjacent to the piles. Topsoil, or the A horizon, is often eroded away because of the loss of vegetation and resultant loss of soil protection. Acidity accelerates the weathering process in the soil profile, producing a more fine-textured material than originally present before mining occurred. These fine materials may result in the occurrence of more sesquioxide-coated (red-colored) minerals in the surface soil (Pearson,1967).

Acidity physically alters soil integrity and increases soil chemical disequilibrium by increasing the solubility of copper, iron, and zinc compounds and several other heavy metals and minerals.

Sulfuric acid produced in the interaction of oxygen and water with sulfides is the chief agent responsible for the lower pH. Studies of heavy metals in mine spoils have indicated that, as pH is lowered, higher concentrations of heavy metals occur (Peterson and Nielson, 1973).

These toxic chemicals can block or interfere with vital physiological

plant processes and contribute to an unhealthy human environment. Prevention of heavy metal solubility and inhibition of pyrite-oxidizing organisms can occur only after the pH is raised.

Belt and Sand Coulee soils have a very sandy to small gravelly texture and are dark in color. Because of the coarse texture, these soils are very permeable, thus water can move through the profile efficiently, both laterally and vertically. Also, oxygen can reach the pyrites more easily as a result of the many interstices between soil particles. The dark color and the extreme lack of vegetation result in greater heat absorption. Due to the barren landscape, there is only one continuous surface over which air can move, decreasing the efficiency of convection current cooling. Evaporative cooling is negligible after the initial water from rainfall is lost. The above factors result in the temperature of the soil surface rising considerably. Bradshaw et. al. (1972) reports that:

> Temperatures of 60^{o}C have been recorded on colliery waste in the U.S. Plants growing sparsely under these conditions will tend to lose water so rapidly that they cannot maintain their water content and expire. But they may also be directly damaged by the heat. The temperature is highest at the soil surface, and so the plant is killed at this point and collapses; this is known as heat girdling.

The carbonaceous material of which most of the tailings piles are composed is slow to weather and produces little in the way of nutrients for plant growth (Chadwick, 1972). At a pH below 5, the essential nutrients nitrogen (N), phosphorus (P), and potassium (K) become less available as heavy metals become more available. Unfortunately, in the case of phosphorous (P), the ideal pH range for minimal metal solubility is also the range of low solubility of P in a calcium-sodium system (Peterson and Neilson, 1973).

Nitrogen deficiencies are probably associated with most, if not all, of the waste piles in the project area. In this climate, the primary

pathways by which atmospheric nitrogen (N_2), the ultimate source of N used by plants, is converted to forms useable by higher plants are:

(1) fixation by rhizobia and other microorganisms living symbiotically on the roots of legumes and certain nonleguminous plants;

(2) fixation as a result of free-living soil microorganisms; and

(3) fixation as one of the oxides of nitrogen by atmospheric electrical discharges (Tisdale and Nelson, 1975).

Since the spoils are almost devoid of plants and the acidic soils associated with them have an inherent very low soil reaction which is below the pH tolerance of legumes, fixation by rhizobia and other symbiotically occurring microorganisms is negligible. Free-living soil bacteria, such as rhizobia, generally favor the same environmental factors as upland agricultural plants.

From the standpoint of soil fertility, the nitrogen complexes ammonium (NH_4+), nitrite (NO_2^-), and nitrate (NO_3^-) are of greatest importance. It is in these forms which nitrogen is available for plant uptake and utilization. Nitrate nitrogen is completely mobile in soils and very susceptible to leaching. NH_4+ is not as mobile as the nitrates, and can be fixed within the clay interlayer by replacing another cation. However, the significance of ammonium fixation to agriculture is not generally considered to be great. Nitrogen is probably the limiting nutrient, however it must be considered carefully, as nitrogenous commercial fertilizer can contribute to soil acidity.

B. Methods

Abandoned mines in the Belt and Sand Coulee vicinity were located through the use of U.S.G.S. base maps with marked sites and tailings piles. These maps were obtained from the contractor, the Department of State Lands (DSL). On-site reconnaissance and examination not only confirmed the

marked sites, but resulted in a few more discoveries. All sites were mapped for future field studies and research work.

Each portal was designated as either dry or discharging and mapped. This segregation was necessary for future research and reclamation proposals.

The U.S.D.A. Soil Conservation Service (SCS) in Cascade County supplied detailed soil series survey maps and accompanying text; the map was reproduced on acetate overlays at a scale of eight inches : 1 mile. It is included as Exhibit B. The soil survey and text provided sufficient detail specificity to aid in the identification of the surrounding soils.

From the SCS information, photographs and from the maps identifying the locations of the portals, preliminary soil sampling sites were determined. Tailings piles that differed in texture and color and were located in different major drainages were sampled for analysis. Unaffected natural soils near tailings piles and affected soils beneath tailings were sampled and their profiles described. These efforts were necessary to determine differences existing between these soils, and to establish toxicity and sterility levels of the contaminated soils. Unaffected and affected soils were sampled on slopes and bottoms near the affected areas to assure adequate representation of the study area. Soil samples were taken directly from the field to Montana Testing Laboratories in Great Falls. A greenhouse study was initiated to utilize results from the chemical analyses to determine treatments necessary to correct acidity (see Appendix C).

Natural, unaffected soil samples were tested for pH, saturation percentage, electrical conductivity, calcium, magnesium, sodium, sodium absorption ratio, texture, nitrates, ammonium and boron. The affected soil samples were tested for the above factors and for the heavy metals; nickel, cadmium, lead, zinc, iron, copper, manganese, mercury, molybdenum and selenium.

The results of these tests, the field information, and the SCS data were used to develop a master plan for the alleviation of problems caused by the derelict mines.

C. Results and discussion

Appendix C divides each soil site sampled into two categories: sites affected by previous coal mining and sites unaffected by mining. Also, included in the table are SCS soil series on which remnant coal mines are present and the soil series immediately below the coal mines. These latter soils could be used for reclamation purposes.

1. Unaffected soils

The unaffected soils that were sampled evolved from two basic backgrounds. Soils on hillsides, used predominantly for range, originated from colluvium which was fractured sandstone with lesser quantities of shales and siltstone. These rocks were of a soft nature and appeared to weather quite easily. Bottom lands which evolved from alluvium are frequently used for hayfields or range, and to a lesser degree, small grains. These soils are deep and stratified with varying sizes of sand, gravel and rock composed mainly of sandstone with periodic lenses of shale, siltstone and infrequent igneous rock.

Unaffected soil sampling sites were selected in juxtaposition to slag piles or portals for comparison with affected soils and for possible reclamation purposes. Site 14, a potential source of topsoil unaffected by mining, was sampled to analyze soil physical and chemical properties.

Among the unaffected soils, steep slopes, depth to bedrock and poor texture remain the major limiting factors for inhibiting plant growth and soil stability. Sites 1A and 16 were located on steep slopes. Sites 1A, 1D, 16, 18 and 21 were comparatively shallow soils. Sites 1A, 1D, 18 and 21

exhibited either excess clay or excess gravels at some level in their profile which could deter plant growth or soil stability without some rehabilitation to overcome these conditions.

Analysis results at site 1D indicate acidity between the depths of 0-6 inches and 12-20 inches. Nickel values were higher than the allowable maximum, probably due to the excess acid in the soil. Site 1D was probably contaminated from runoff originating in the coal slag pile upstream from the site. The high acidity and the level of nickel present appear to conflict with the productive hay crop that was grown on the area.

Soils sampled at sites 14 and 24 show allowable physical and chemical parameters throughout their deep profiles. Both soils evolved from alluvium and are located on stream terraces.

2. Affected soils

Soil sites affected by past mining display three common characteristics: they display acid soils in at least the upper portion of their profiles; they are barren of vegetation; and they are easily subject to erosion. Site 3A, located under a cinder pile, does not show signs of acidity. This might have occurred because the sample was taken from an area that has recently been covered with cinder. This site was used to provide fill material and disturbance to the pile probably spread cinder to a recently unaffected area. Sites 19, 20 and 23 show lesser amounts of erosion than the other affected areas. This is probably due to the nearly level terrain and rapid permeability rates. Appearances on these sites may be misleading; sheet erosion, which is difficult to detect, may be occurring.

The affected sites which have undesirable soil textures are sites 2A, 2B, 9, 19 and 20. Excessive sands throughout sites 19 and 20 provide for poor

texture. Clayey soils are found at sites 2A (2-12 inches) and from 12 to 34 inches, 2B (0-12 inches), and 9 (0-6 inches). Extremely sandy soils tend to excessively drain soil water, leaving little water for plant uptake. Heavy clay soils do not allow for adequate drainage and promote surface runoff. Water which does percolate into a clayey soil can be retained at such great pressure that plants are unable to extract the water.

The presence of high levels of heavy metals occurs on a number of sites. Iron was detected in above tolerable levels in sites 2A, 2C, 8, 12, 13, 13B, 15 and 23. Boron was above maximum limits in sites 2C and 3B. Manganese was above maximum limits in sites 8 and 17. Nickel and copper levels were high in sites 8 and 15, respectively. High levels of heavy metals can be toxic to plants and animals if consumed in large enough quantities.

Sites 1C, 2C, 3A, 3B, 4A, 5A, 6, 8, 12, 13, 15, 19, 20 and 22 displayed excessive fine gravels and gravels. Of these, sites 1C, 2C, 3B, 8, 13B and 22 were gob or slag piles where gravel size pieces of coal or cinders dominated the texture. Drainage is excessive, due to large pore spaces; this places extremely draughty conditions on plant life. Laboratory data shows these soils to be capable of holding adequate to more than adequate water at saturation; however, these soils lose water so rapidly that at "field capacity" (sufficient amount of water held by pore spaces for a reasonable amount of time for plant root use) these soils are devoid of any water for plant root use.

Poor consistence is another indication of undesirable textures which inhibits or nullifies plant use of soil water. This occurs in soils with either excessive clays or fine silts or those soils exhibiting large amounts of sand. These poor conditions are prevalent in sites 1B, 1C, 2C, 3A, 3B,

8, 11, 13B, 13, 20, 22 and 23. Again, sites 1C, 2C, 3A, 3B, 8, 13B and 22 are cinder or coal gob piles. Poor consistence usually occurs as a stratification within a soil profile. Therefore, if a soil contains a layer of soil that displays heavy clays prone to forming a poor layer or an impermeable horizon (especially at shallow depths), these soils can affect water infiltration and subsequent plant water use. Sandy soils are not as detrimental unless a very sandy or gravelly consistence is prevalent throughout the soil profile.

Shallow soils with little depth to bedrock or parent material, occur in sites 2A, 2B, 4A, 5A, 6, 7A, 9, 10, 13, 20 and 23. These sites contain soils less than 45 inches in depth which restrict rooting depth. Shallow soils can be more conducive to erosion than deeper soils.

Shallow watertables, depths of 26 inches and 36 inches, respectively, were discovered at sites 12 and 13. Shallow watertables present a problem due to the relative ease with which the groundwater can be polluted from surface activities.

Sites 1C, 2A, 2B, 2C, 3B, 7A, 8, 9, 11, 12 and 13B are located on steep slopes. Steep slopes present safety problems when reclamation efforts are undertaken and soil erosion can be a problem if these soils are left barren.

Sites 3C, 3B and 8 are gob or cinder piles. Their high electrical conductivity levels are probably enhanced by the high amounts of hydrogen (H) or aluminum hydrogen (AlH) ions in these soils. This fact is supported by the extremely low pH's prevalent.

Sites 9, 11, 12 and 13 are poorly drained due to the occurrence of a high watertable and/or heavy clays. The soils on these sites indicate the presence of acidic conditions caused by the coal slag piles. It may be

assumed that the water is also acidic. This water penetrating to the groundwater table carries with it acidity and subsequent pollution.

III. Vegetation

A vegetation inventory was conducted in September, 1980 at the Belt and Sand Coulee project areas on land disturbed by past coal mining operations.

Objectives of the inventory, as outlined in the study plan submitted to the Department of State Lands (DSL), were to:

1. Provide a qualitative description of plant communities,
2. Delineate plant community types,
3. Establish a species list of vascular plants in the study area.

A. Literature review

The Belt-Sand Coulee area southeast of Great Falls is dominated by gently undulating to rolling limestone plains dissected by deep drainageways and coulees.

Nearly level flood plains and gently sloping fan terraces along Sand Coulee Creek grade into steeper land broken by numerous intermittent drainage channels. Local relief varies from 25 feet to 300 feet.

The Belt Creek Valley forms a narrow strip of floodplain and low terraces which break east of Belt into dissected red shale uplands and steep slopes. Rolling limestone uplands with steep slopes comprise the area west of Belt (SCS 1969).

The climate of this area has been characterized as warm in summer and cold in winter with an average annual temperature of 45°F. Winter cold spells are usually broken by chinook winds. Precipitation averages

10-14 inches annually with most of this amount falling during the April - September growing season.

The Belt-Sand Coulee area is a cool, semi-arid mixed short-and mid-grass prairie. Kuchler (1975) has included this area as part of the central and eastern grasslands of the United States, characterized by a grama-needlegrass and wheatgrass (Bouteloua-Stipa-Agropyron) association.

Climax vegetation is determined by soil and climatic factors. Range sites describe a native plant community in climax condition that is typified by a consistent amount and type of vegetation species. Ross and Hunter (1976) have mapped the area in which the majority of mines in the Belt-Sand Coulee area are located as Western Glaciated Plains, clayey and shallow clay range sites, 10-14 inches precipitation zone.

The southernmost extension of the area dominated by previous mining is included in the Foothills and Mountains silty range site, 15-19 inches precipitation zone. Dominant plant species for each range site are as follows:

Western Glaciated Plains clayey and shallow clay range sites 10-14 inches precipitation zone	Green needlegrass Western and thickspike wheatgrass Bluebunch wheatgrass Needle-and-thread Prairie junegrass Plains reedgrass Milkvetch Scarlet globemallow Winterfat Prairie sandreed
Foothills and Mountains silty range sites 15-19 inches precipitation zone	Rough fescue Idaho fescue Bluebunch wheatgrass Columbia needlegrass Basin wildrye Spike fescue

Foothills and Mountains (cont.)	Parry danthonia Slender wheatgrass Lupine Sticky geranium Arrowleaf balsamroot Prairie smoke Big sagebrush Tall larkspur Prairie junegrass Timber danthonia Big bluegrass

Land use is primarily dryland farming and grazing with irrigated hay meadows occurring along major drainages (Montana State Engineers Office, 1961). Coal mining on the slopes above creek bottoms has been abandoned since the 1950's.

B. Methods

1. Sampling and transect design

Six transects were located at sites of past mining activity in the vicinity of Belt, Montana in September, 1980. Thirteen transects were located at similar sites during the same period in the communities of Tracy, Sand Coulee, Stockett and Centerville (considered cumulatively as the Sand Coulee area). Transects were established to quantitatively determine canopy coverage and frequency of occurrence.

Distribution of transects was based on analysis of aerial photos and was field checked during a preliminary reconnaissance. Transects were located adjacent to gob piles (which were, for the most part, devoid of vegetation) to best represent the area vegetatively. They were distributed to provide thorough geographic coverage of the project area, in a somewhat restricted elevation zone ranging from 3465 feet to 4000 feet. This zone corresponded

to those areas of past mining activity along coal seams; therefore, no transects were placed on drainage bottoms. Transect locations are mapped alphabetically on U.S.G.S. base acetate overlays in Exhibit C.

Transects generally occurred on two soil units: a shallow, rocky sandy loam of sedimentary uplands and a deeper gravelly loam of fans and foot slopes.

Canopy coverage was measured by stretching a 40 m tape between two points, following the contour of the terrain. An ocular estimate of percent canopy coverage of all vascular plants, bare ground, rock, litter, lichens and mosses was recorded for each of twenty (20) 2 x 5 dm Daubenmire plots placed at 2 m intervals on alternate sides of the tape. Species which did not appear in the plots but were present in the stand were recorded on data sheets.

Mean percent canopy coverage for each plant species, as well as bare ground, rock, litter, lichens and mosses was calculated by transect. Percent species frequency was also determined by transect.

Site descriptions recorded on each transect data sheet included location to the nearest quarter section, stand number, date, personnel, percent slope, aspect, soil elevation, topography and configuration (see Appendix D).

Photographic documentation was made of each transect location, including a close-up and general view shot (see Appendix E).

2. Vegetation type delineation

Vegetation types were identified using transect canopy coverage data; each type was named for two dominant plant species. Type descriptions were supplemented with information regarding environmental factors, soils, physiography and past history of use.

Canopy coverage data and a general pedestrian reconnaissance served as ground truth for vegetation mapping.

3. Species list

A comprehensive species list of vascular plants was compiled during the data collection period. Taxonomy and nomenclature followed Hitchcock and Cronquist (1973). Supplemental references included: Hitchcock et al. (1955-1979), Booth (1972), Booth and Wright (1966), Hitchcock and Chase (1971), Johnson and Nichols (1970) and Van Bruggen (1976). Unknown plant specimens were collected and pressed for subsequent laboratory identification using a Bausch and Lomb Stereozoom 5 dissection microscope (see Appendix F).

C. Results and discussion

1. Vegetation type descriptions

Four vegetation types identified in the Belt-Sand Coulee project area are presented below:

Vegetation Type	Dominant Species
RHTR/AGSP	*Rhus trilobata*/*Agropyron spicatum* (skunkbush sumac/bluebunch wheatgrass)
MIXED GRASSLAND	*Agropyron spicatum*/*Agropyron smithii*/*Bouteloua gracilis* (bluebunch wheatgrass/western wheatgrass/blue grama)

Vegetation Type	Dominant Species
MIXED SHRUB/POPR	*Rhus trilobata/Symphoricarpos occidentalis/Poa pratensis* (skunkbush sumac, snowberry, Kentucky bluegrass)
SYOC/POPR	*Symphoricarpos occidentalis/Poa pratensis* (western snowberry/ Kentucky bluegrass)

A summary of transect and mine designation by type is included in Appendix G.

a. Skunkbush sumac/bluebunch wheatgrass

The skunkbush sumac/bluebunch wheatgrass (*Rhus trilobata/Agropyron spicatum*) vegetation type commonly occupies steeper, south-facing slopes. It is found on lower to mid-elevation sedimentary uplands having shallow, well-drained gravelly loam soils. Mean percent coverage by rock is 27.6 percent, which is comprised of sandstone and shale fragments weathered from sandstone, argillite, or quartzite. Physiographic features of each vegetation type are listed in Table 1.

This type has the lowest total percentage of vegetational cover (33 percent) of the four vegetation types identified. This is in part attributable to the relatively unstable soils of steep slopes.

Sumac, the dominant shrub for which this type is named, has an average canopy coverage of 7.1 percent. Other species constitute the remaining 2.1 percent cover by woody plants.

The dominant graminoid on all transects in this type is bluebunch wheatgrass, with an average cover of 10.8 percent. Other important grasses include blue grama (*Bouteloua gracilis*) at 2.0 percent cover and Canada bluegrass (*Poa compressa*) at 1.7 percent.

Table 1. Physiographic features by community type, Belt-Sand Coulee area, Montana, 1980.

TYPE	% SLOPE		ASPECT		ELEVATION		SOILS	TOPOGRAPHY	CONFIGURATION
	Range	Average	Range	Average	Range	Average			
RHTR/AGSP	42-75	55	123-338	214	3540-3780	3660	rocky sandy loam (shallow)	lower slope-midslope	convex
MIXED GRASSLAND	0-34	20	86-345	varies	3465-3920	3679	gravelly loam (deep)	lower slope-ridge	undulating
MIXED SHRUB/ POPR	32-65	45	164-342	279	3540-4000	3708	rocky, sandy loam (shallow)	midslope	undulating
SYOC/POPR	16-46	27	79-350	varies	3520-3950	3673	gravelly loam (deep)	lower slope	convex-undulating

Important forbs are fringed sagewort (Artemisia frigida) with 1.2 percent cover and prairie pepperweed (Lepidium densiflorum) with 0.7 percent cover.

b. Mixed grassland

The mixed grassland vegetation type is generally found on gentle slopes or ridges with an undulating topographical configuration at stand elevations ranging from 3465 to 3920 feet. Aspect of this type is variable. Soils are deep, well-drained gravelly loams formed in alluvium, colluvium, and slopewash.

Total vegetational cover is somewhat low in this type at 36.1 percent; litter is relatively high at 58.1 percent. Woody species comprise only 0.7 percent of total cover.

Prevalent grass species and their respective percent canopy coverage estimates are: bluebunch wheatgrass (5.6 percent), blue grama (5.5 percent), Kentucky bluegrass (3.8 percent), prairie junegrass (Koeleria cristata) with 2.4 percent, needle-and-thread (Stipa comata) with 2.4 percent and western wheatgrass (1.9 percent).

Important forb species include hairy goldenaster (Chrysopsis villosa) with 1.8 percent cover, fringed sagewort (1.2 percent cover) and broom snakeweed (Xanthocephalum sarothrae) with 1.7 percent cover. Total forb coverage in this type exceeds that of the other vegetational types.

c. Mixed shrub/Kentucky bluegrass

The vegetation type designated as mixed shrub/Kentucky bluegrass is co-dominated by both moist and dry site species. The stands occur on midslopes at elevations of 3540 feet to 4000 feet. Aspect is west-northwesterly. This type generally occurs on shallower gravelly loam

soils and on rocky clay soils derived from shales.

Total vegetational cover is 43.8 percent. Drier upland shrub components include skunkbush sumac (4.6 percent cover) and Arkansas rose (*Rosa arkansana*, 1.4 percent cover). Moist-site woody species that occur in lower elevations near riparian bottoms or in swales are western snowberry (2.4 percent), hawthorn (*Crataegus douglasii*) with 2.0 percent, serviceberry (*Amelanchier alnifolia*) with 1.2 percent cover and chokecherry (*Prunus virginiana*) with 0.8 percent.

In all stands sampled, Kentucky bluegrass has a consistently dominant canopy coverage with an average of 14.4 percent. Other important grasses are: bluebunch wheatgrass (commonly in association with skunkbush sumac) at 4.3 percent cover, western wheatgrass (1.0 percent) and needle-leaf sedge (*Carex eleocharis*, 0.9 percent). The presence of Kentucky bluegrass indicates prior disturbance and subsequent invasion, probably due to the combined effects of mining and grazing.

d. Western snowberry/Kentucky bluegrass

Topographic characteristics (lower, undulating slopes) and proximity to creek bottoms dictate the floristic features of this type. These stands are almost always associated with tame pastures and riparian bottoms. The aspect is variable, slopes are gentle, and elevations range from 3520 to 3950 feet. The sites are located on outwash fans composed of gravelly loam soils.

Total vegetational cover for this type (61.7 percent) is higher than for the other three types. There is a roughly equivalent proportion of

graminoid cover (29.8 percent) and woody species cover (25.0 percent).

Western snowberry dominates this type with a canopy coverage of 10.9 percent. Black hawthorn has a higher percent cover (12.0) but occurs on just one transect. Other shrubs of importance are Arkansas rose and serviceberry.

Kentucky bluegrass averages 23.3 percent coverage with a 60 percent frequency. Smooth brome (*Bromus inermis*), an escaped pasture species, accounts for 1.7 percent cover; western wheatgrass and green needlegrass (*Stipa viridula*) are also present in this type.

2. Canopy coverage data

Canopy coverage and constancy for all species by vegetation type is presented in Table 2. Table 3 lists percent canopy coverage and frequency of vegetation by transect by vegetation type. Total mean percent canopy coverage by class for vegetation types appears in Table 4.

The snowberry/Kentucky bluegrass type has the highest total vegetational cover; skunkbush sumac/bluebunch wheatgrass has the lowest. This is probably due to moisture factors, with snowberry/Kentucky bluegrass being the most mesic of all types sampled. The sumac/wheatgrass type occurs on steep slopes removed from water.

Table 2. Percent canopy coverage and constancy of all species by vegetation type, Belt-Sand Coulee Project, Montana, 1980.

	Rhtr/Agsp n=5	Mixed Grassland n=5	Mixed Shrub/Popr n=5	Syoc/Popr n=4
GRAMINOIDS				
Agropyron smithii	.8/80	1.9/80	1.0/80	1.2/100
Agropyron spicatum	10.8/100	5.6/80	4.3/80	.5/50
Aristida longiseta	1.0/20		T/20	
Bouteloua gracilis	2.0/60	5.5/60	.1/40	T/25
Bromus inermis				1.7/25
Bromus japonicus	1.0/100	.7/80	.1/60	.5/50
Bromus tectorum	.3/60		T/20	
Calamagrostis montanensis		.1/40	.2/40	
Carex eleocharis	.1/20	1.1/100	.9/60	.7/75
Carex filifolia		T/20		
Festuca idanoensis				.3/25
Koeleria cristata		2.4/60		
Phleum pratense			T/20	
Poa compressa	1.7/60	.2/20		
Poa pratensis		3.8/80	14.4/100	23.3/100
Poa sandbergii		T/20		
Stipa comata		2.4/80	T/20	.6/25
Stipa viridula	.9/60	.6/40	.7/60	.9/75
Vulpia octoflora				T/25

Table 2. (Cont.)

	Rhtr/Agsp n=5	Mixed Grassland n=5	Mixed Shrub/Popr n=5	Syoc/Popr n=4
FORBS				
Achillea millefolium	T/20	.3/80	.4/80	.3/50
Allium textile	T/20			
Antennaria spp.		T/20	.3/20	T/25
Arabis holboellii	T/20			
Artemisia absinthium				.2/25
Artemisia dracunculus		T/20		.1/25
Artemisia ludoviciana			.2/40	.2/75
Aster chilensis	T/20			
Aster falcatus	.5/60	.8/100	.6/80	.8/100
Astragalus spp.		.2/40	T/60	.1/50
Balsamorhiza sagittata		T/20	.5/40	T/25
Camelina microcarpa	T/20	T/20		T/25
Campanula rotundifolia				T/25
Cerastium arvense	.3/20	.7/60	.3/100	T/25
Chrysopsis villosa	.3/60	1.8/100	.8/20	.1/75
Cirsium arvense				.1/25
Cirsium undulatum	T/20	.1/40		
Clematis ligusticifolia			.2/40	
Comandra umbellata	T/20	.3/40	.2/60	T/25

Table 2. (Cont.)

	Rhtr/Agsp n=5	Mixed Grassland n=5	Mixed Shrub/Popr n=5	Syoc/Popr n=4
FORBS (Cont.)				
Cryptantha interrupta			T/20	
Cynoglossum officinale				T/25
Delphinium bicolor			.1/20	
Erigeron spp.	T/20	.3/60	T/40	.3/25
Fragaria vesca			.3/20	
Galium boreale			.3/20	
Gaura coccinea		T/60	.1/20	.2/1
Geum triflorum		.1/20		
Geranium viscosissimum			T/20	
Glycyrrhiza lepidota				.4/25
Grindelia squarrosa		.2/40	.1/40	
Haplopappus spinulosus		T/20		
Lactuca serriola	T/20			
Lepidium densiflorum	.7/80	.6/80	.1/40	.2/75
Liatris punctata		.3/60	T/20	.2/25
Linum perenne	.1/40	T/20	T/20	.1/25
Linaria vulgaris				
Lithospermum arvense	.1/20			
Lupinus sericeus		.5/40	.3/40	1.8/25
Lygodesmia juncea		T/20		

Table 2. (Cont.)

	Rhtr/Agsp n=5	Mixed Grassland n=5	Mixed Shrub/Popr n=5	Syoc/Popr n=4
FORBS (Cont.)				
Monarda fistulosa			.8/60	.2/75
Opuntia polyacantha	.1/40			
Penstemon spp.				.1/25
Petalostemon purpureum	T/20	T/20	T/20	T/25
Phlox hoodii	T/20	.4/60		
Potentilla spp.			T/20	
Psoralea esculenta			T/20	
Psoralea tenuiflora		T/20	.2/20	
Ratibida columnifera			T/20	
Senecio spp.		.1/20		.1/25
Sisymbrium loeselii	T/20			T/25
Solidago missouriensis	T/20	T/60	.8/80	.2/75
Solidago rigida			.5/60	
Sphaeralcea coccinea	.1/40	.1/60	T/20	T/25
Taraxacum officinale	T/20	T/20	T/20	T/25
Thalictrum occidentale			T/20	
Thermopsis rhombifolia	.2/40	.2/40		.1/25
Tragopogon dubius	.3/80	.4/60	.3/100	.1/75
Trifolium spp.	T/20		.2/20	T/25
Verbascum thapsus	.1/40			
Vicia americana	.3/60	.2/60	T/20	
Viola spp.				T/25

Table 2. (Cont.)

	Rhtr/Agsp n=5	Mixed Grassland n=5	Mixed Shrub/Popr n=5	Syoc/Popr n=4
SUBSHRUBS				
Artemisia frigida	1.2/80	1.2/80	.2/100	.3/100
Xanthocephalum sarothrae	T/20	1.7/60	.3/60	T/50
SHRUBS				
Amelanchier alnifolia	.5/40		1.2/80	.4/50
Prunus virginiana	T/20		.8/80	.1/25
Rhus trilobata	7.1/100		4.6/80	
Ribes setosum				T/25
Rosa arkansana	.4/40	.5/20	1.4/80	1.5/50
Symphoricarpos occidentalis	.6/60	.2/20	2.4/100	10.9/100
TREES				
Crataegus douglasii	.5/20		2.0/60	12.0/25

Table 3. Percent canopy coverage and frequency of vegetation by transect by vegetation type and mean percent canopy coverage and frequency of vegetation species by type, Belt-Sand Coulee Project area, Montana, 1980 (note: %C = percent canopy coverage, F = frequency of occurrence, T = 0.1% cover).

RHTR/AGSP

	A		B		F		N		O		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
BARE	33.8	100	8.8	70	16.4	100	12.2	90	14.2	75	17.1	87
ROCK	21.0	100	14.9	80	39.8	100	46.5	95	30.6	100	27.6	95
LITTER	38.7	100	75.2	100	42.8	90	37.4	95	50.2	95	48.9	96
LICHENS	3.8	100	.9	45	.9	65	3.7	90	5.7	90	3.0	78
MOSS	2.6	75	0	0	T	10	.2	15	.2	5	.6	21
GRAMINOIDS:												
AGSM	0.8	45	1.9	60			1.0	60	T	5	.75	34
AGSP	13.4	100	7.2	95	9.6	90	11.9	90	11.8	100	10.8	95
ARLO							1.0	10	4.0	35	1.0	9
BOGR	4.3	50	1.2	20					4.4	55	2.0	25
BRJA	0.2	30	0.7	45	1.8	55	1.2	45	1.0	30	1.0	41
BRTE	0.7	15	0.3	15					0.3	20	0.3	10
CAEL							0.4	15			.1	3
POCO	4.1	35			2.6	40	1.6	35			1.7	22
STVI	1.0	20	3.3	45			0.2	10			.9	15
Total G.											18.6	

SPECIES	A		B		F		N		O		MEAN	
	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS/SUBSHRUBS:												
ACMI					T	5					T	1
ALTE					0.2	5					T	1
ARHO									T	5	T	1
ASCH			0.1	10							T	2
ASFA			0.2	15			0.7	10	1.7	10	.5	7
CAMI									T	5	T	1
CEAR					1.6	25					.3	5
CHVI	0.9	30			0.2	5	0.2	5			.3	8
CIUN									0.2	10	T	2
COUM	0.1	10									T	2
ERIGERON	0.1	10									T	2
GRSQ					0.1	5			T	5	T	2
LASE					0.2	5					T	1
LEDE	1.0	70	0.6	35	0.1	10	1.8	70			.7	37
LIPE	0.3	20			0.4	15					.1	7
LIAR									0.3	15	.1	3
OPPO	0.1	5	0.3	10							.1	3
PEPU	0.2	100									T	20
PHHO							0.2	5			T	1
SILO									T	5	T	1
SOMI									0.3	30	T	6
SPCO							0.4	10	0.2	10	.1	4

	A		B		F		N		O		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS (cont.)												
TAOF							0.2	5			T	1
THRH					0.8	20	0.2	10			.2	6
TRDU			T	10	0.3	20	1.0	15	T	5	.3	10
TRIFOLIUM			T	5							T	1
VETH					0.2	10			0.4	5	.1	3
VIAM	T	10	1.4	45			T	5			.3	12
ARFR	0.6	25			2.0	40	0.6	10	2.6	55	1.2	26
XASA	0.3	10									T	2
Total F.											5.2	
WOODY PLANTS, etc.												
AMAL	1.2	10			1.4	30					.5	8
CRDO			2.4	10							.5	2
PRVI					0.1	10					T	2
ROAR					0.6	10	1.2	30			.4	8
RHTR	7.4	25	14.0	60	2.6	20	7.0	10	4.7	30	7.1	29
SYOC	0.5	10			1.8	40	0.6	15			.6	13
Total W.											9.2	
Total Veg.											33.0	

MIXED GRASSLAND

SPECIES	J %C	J F	K %C	K F	I %C	I F	R %C	R F	S %C	S F	MEAN %C	MEAN F
BARE	20.7	100	22.6	100	37.8	100	21.6	100	27.4	100	26.0	100
ROCK	2.2	65	6.1	95	10.4	80	14.8	90	1.5	90	7.0	84
LITTER	76.6	100	69.9	100	51.0	100	48.0	100	44.9	100	58.1	100
LICHENS	.3	25	1.3	80	.5	40	4.2	90	4.9	95	2.2	66
MOSS	.2	10	T	5	.2	10	10.4	95	20.1	85	6.2	41
GRAMINOIDS:												
AGSM			0.1	10	2.8	80	3.1	90	3.6	100	1.9	56
AGSP	13.5	100	10.7	100	2.6	55	1.0	30			5.6	57
BOGR			8.8	85			8.8	80	10.1	95	5.5	52
BRJA	1.2	50	0.5	20	T	5	1.5	30			.7	20
CAMO	0.2	10					0.5	15			.1	5
CAEL	2.0	70	T	5	1.6	60	0.3	20	1.7	60	1.1	43
CAFI					0.3	10					T	2
KOCR			6.4	95			1.6	80	4.2	70	2.4	49
POCO					1.2	15					.2	3
POPR	4.9	65	0.2	15	6.7	65	7.2	75			3.8	44
POSE							0.2	5			T	1
STCO			2.6	35	2.4	40	2.5	60	4.3	90	2.4	45
STVI			1.4	35			1.6	30			.6	13
Total G.											24.4	

	J		K		I		R		S		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS/SUBSHRUBS:												
ACMI	T	5	0.1	5	0.2	5	0.2	15			.3	6
ANTENNARIA			T	5							T	1
ARDR							1.0	10			T	2
ASFA	T	5	0.2	5	0.5	20	0.9	40	0.4	15	.8	17
ASTRAGALUS			0.6	10					0.2	10	.2	4
BASA			0.2	10							T	2
CAMI			T	5							T	1
CEAR	T	5			0.2	10	1.4	45			.7	12
CHVI	0.2	10	3.3	55	3.8	45	1.4	65	0.4	30	1.8	41
CIUN					0.3	10	0.2	5			.1	3
COUM	1.1	45			0.4	25					.3	14
ERIGERON			0.1	5	T	5	0.2	15			.3	5
GACO			T	5	T	5	0.2	25			T	6
GETR							0.6	20			.1	4
GRSQ	0.2	5			0.8	5					.2	2
HASP									0.2	5	T	1
LEDE	0.7	50	1.2	65	0.2	10	0.8	55			.6	36
LIPU			1.0	30	0.2	10	0.2	10			.3	10
LIPE			0.2	10							T	2
LUSE	0.5	20	2.1	35							.5	11
LYJU							0.2	10			T	2
PEPU							0.3	15			T	3

	J		K		I		R		S		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS (cont.)												
PHHO	1.0	15	0.1	5					0.8	25	.4	9
PSTE							0.2	10			T	2
SENECIO							0.4	5			.1	1
SOMI			0.1	5			0.1	25	T	5	T	7
SPCO			T	5	0.2	5	0.2	15			.1	5
TAOF							T	5			T	1
THRH			0.1	5	0.7	20					.2	5
TRDU	0.1	10	1.6	45	0.2	10					.4	13
VIAM			0.2	10	0.8	15	0.1	5			.2	6
ARFR	0.1	5	3.2	70	0.8	25	1.6	70	0.5	25	1.2	39
XASA			0.7	10			0.6	30	7.3	95	1.7	27
Total F.											11.0	
WOODY PLANTS, etc.												
ROAR	2.4	70									.5	14
SYOC	1.0	35									.2	7
Total W.											.7	
Total Veg.											36.1	

MIXED SHRUB/POPR

	C		E		G		M		P		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
BARE	33.6	100	10.8	55	24.2	85	3.8	65	14.2	75	17.3	76
ROCK	1.6	80	9.8	65	2.1	30	1.8	20	16.4	25	6.3	44
LITTER	53.2	85	75.2	95	69.0	95	94.4	95	71.8	100	72.7	94
LICHENS	.1	10	1.2	55	.2	25	.4	15	1.7	65	.7	34
MOSS	8.0	85	.1	10							1.6	19
GRAMINOIDS:												
AGSM	0.4	15			2.1	55	2.4	85	0.2	30	1.0	37
AGSP			6.0	70	0.8	20	7.2	95	7.7	90	4.3	55
ARLO			1.0	10							T	2
BOGR			0.4	10	T	5					.1	3
BRJA					0.4	20	0.1	15	0.1	10	.1	9
BRTE					0.2	5					T	1
CAEL	0.8	15			3.0	45			0.8	20	.9	16
CAMO			0.6	15	0.2	15					.2	6
PHPR	0.2	20									T	4
POPR	25.0	100	11.5	75	10.1	70	15.0	95	10.6	95	14.4	87
STCO					0.2	5					T	1
STVI	1.8	15	0.8	15			1.0	15			.7	9
Total G.											21.9	

SPECIES	C %C	C F	E %C	E F	G %C	G F	M %C	M F	P %C	P F	MEAN %C	MEAN F
FORBS/SUBSHRUBS:												
ACMI	0.7	30	0.5	30	0.8	25	T	5			.4	18
ANTENNARIA					1.3	5					.3	1
ARLU					0.4	10	0.4	10			.2	4
ASFA	0.2	5			0.8	30	1.7	35	0.4	15	.6	17
ASTRAGALUS	0.2	10	T	5	T	5					T	4
BASA			2.2	10			0.2	5			.5	3
CEAR	0.1	10	0.2	5	0.1	10	0.2	10	0.8	25	.3	12
CHVI			3.9	60							.8	12
CLLI	0.4	5	0.4	5							.2	2
COUM			T	5	0.4	20			0.3	10	.2	7
CRIN					T	5					T	1
DEBI	0.4	20									.1	4
ERIGERON					0.1	10			0.1	5	T	3
FRVE	1.4	30									.3	6
GABO	1.7	65									.3	13
GACO									0.5	5	.1	1
GEVI	0.2	10									T	2
GRSQ	0.2	10					0.2	5			.1	3
LEDE			T	10	0.4	45	0.1	15	0.1	10	.1	16
LIPU									0.2	5	T	1
LIPE			0.2	20							T	4
LUSE	0.3	5			1.0	25					.3	6

	C		E		G		M		P		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS (cont.)												
MOFI	0.7	20			0.8	15	2.4	25			.8	12
PEPU					0.3	10					T	2
POTENTILLA							T	5			T	1
PSES			0.2	5							T	1
PSTE									0.8	30	.2	6
RACO					0.3	15					T	3
RHRA	T	5					2.8	25	0.4	10	.7	8
SOMI	1.8	50			0.6	25	0.6	5	1.0	5	.8	17
SORI			T	5	1.3	25	1.2	5			.5	7
SPCO							0.1	5			T	1
TAOF	0.2	10									T	2
THOC	0.2	10									T	2
TRDU	T	5	0.4	15	0.1	5	0.2	5	0.9	20	.3	10
TRIFOLIUM	0.9	25									.2	5
VIAM			0.2	15							T	3
ARFR	T	5	0.1	5	0.1	5	0.4	5	0.4	15	.2	7
XASA	0.4	25			0.7	20	0.4	5			.3	10
Total F.											9.5	
WOODY PLANTS, etc.												
AMAL	4.1	60	0.2	5			0.6	5	1.2	20	1.2	18
CRDO	2.4	40	1.0	30			6.8	20			2.0	18

SPECIES	C		E		G		M		P		MEAN	
	%C	F	%C	F	%C	F	%C	F	%C	F	%C	F
WOODY PLANTS etc. (Cont.)												
PRVI	1.0	30	1.3	10			1.3	20	0.2	15	.8	15
RHTR			7.0	75	9.1	20	1.2	25	5.8	20	4.6	28
ROAR	0.2	10			2.8	65	1.6	25	2.4	55	1.4	31
SYOC	3.1	60	4.6	40	1.8	35	1.8	35	0.8	30	2.4	40
Total W.											12.4	
Total Veg.											43.8	

SYOC/POPR

	H		D		L		Q		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F
BARE	4.4	60	.6	25	7.5	50	16.6	85	7.3	55
ROCK					2.0	30	3.0	45	1.2	18.8
LITTER	95.0	100	99.4	100	89.2	100	79.1	100	90.7	100
LICHENS	.2	20			.1	20	.4	15	.2	13.8
MOSS	.4	35					.8	25	.3	15
GRAMINOIDS:										
AGSM	1.2	60	1.4	20	3.1	75	0.4	35	1.2	38
AGSP					0.6	25	2.0	45	.5	14
BOGR					0.2	5			T	1
BRIN			8.4	55					1.7	11
BRJA					2.4	60	0.1	10	.5	14
CAEL	0.6	15			1.7	60	1.0	40	.7	23
FEID							1.4	30	.3	6
POPR	55.6	100	27.2	50	12.5	50	21.0	100	23.3	60
STCO					3.2	25			.6	5
STVI	0.1	5			3.6	30	0.6	15	.9	10
VUOC							0.2	5	T	1
Total G.									29.8	
FORBS/SUBSHRUBS:										
ACMI	1.0	30					0.6	30	.3	12
ANTENNARIA							T	5	T	1

	H		D		L		Q		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS (cont.)										
ARAB			0.9	10					.2	2
ARDR							0.4	5	.1	1
ARLU	0.7	10			T	10	0.2	10	.2	6
ASFA	0.8	30	0.8	20	0.9	25	1.4	50	.8	25
ASTRAGALUS	0.1	5					0.4	20	.1	5
CAMI					T	5			T	1
CARO							0.1	5	T	1
CEAR							T	5	T	1
CHVI	0.4	15	T	5	T	5			.1	5
CIAR			0.6	15					.1	3
COUM							0.2	5	T	1
CYOF	0.2	5							T	1
ERIGERON							1.5	45	.3	9
GACO			1.0	5					.2	1
GLLE					2.1	20			.4	4
LEDE	0.2	15			0.8	40	T	5	.2	12
LIPU					1.0	10			.2	2
LIPE					0.7	10			.1	2
LUSE							9.0	85	1.8	17
MOFI	0.2	15	0.3	5			0.6	5	.2	5
PENSTEMON							0.5	10	.1	2
PEPU					T	5			T	1

	H		D		L		Q		MEAN	
SPECIES	%C	F	%C	F	%C	F	%C	F	%C	F
FORBS (cont.)										
SENECIO							0.4	10	.1	2
SILO					0.2	5			T	1
SOMI	0.2	5	0.5	5			0.2	5	.2	3
SPCO					T	5			T	1
TAOF							0.2	5	T	1
THRH							0.6	25	.1	5
TRDU	0.1	5			0.3	5	0.2	10	.1	4
TRIFOLIUM			T	5					T	1
VIOLA							0.2	5	T	1
ARFR	0.5	25	T	5	0.4	15	0.6	25	.3	14
XASA			0.2	5			0.1	5	T	2
Total F.									6.9	
WOODY PLANTS, etc										
AMAL			1.2	5			0.8	15	.4	4
CRDO			59.8	35					12.0	7
PRVI							0.4	10	.1	2
RIBES							0.2	5	T	1
ROAR			5.7	50			2.0	45	1.5	19
SYOC	12.8	85	31.6	100	7.8	45	2.2	45	10.9	55
Total W.									25.0	
Total Veg.									61.7	

Table 4. Summary of mean percent canopy cover by class for vegetation types, Belt-Sand Coulee area, Montana, 1980.

	VEGETATION TYPE			
	Rhtr/Agsp	Mixed Grassland	Mixed Shrub/Popr	Syoc/Popr
Bare ground	17.1	26.0	17.3	7.3
Rock	27.6	7.0	6.3	1.2
Litter	48.9	58.1	72.7	90.7
Lichens	3.0	2.2	.7	.2
Moss	.6	6.2	1.6	.3
Graminoids	18.6	24.4	21.9	29.8
Forbs	5.2	11.0	9.5	6.9
Woody plants, etc.	9.2	.7	12.4	25.0
Total Vegetation Cover	33.0	36.1	43.8	61.7

3. Weedy species

The following weedy species were found in the project area: most weedy species were encountered on the periphery, or growing directly on the gob piles.

Asteraceae	
Arctium minus	common burdock
Cirsium arvense	Canada thistle
Lactuca pulchella	blue-flowered lettuce
Tanacetum vulgare	tansy
Convolvulaceae	
Convolvulus arvensis	field bindweed
Euphorbiaceae	
Euphorbia spp.	spurge
Poaceae	
Agropyron repens	quackgrass
Scrophulariaceae	
Linaria vulgaris	bastard toadflax

4. Threatened or endangered species

No species considered to be threatened or endangered in Montana were encountered.

IV. Review of Armington pneumatic injection demonstration

The coal refuse pile at Armington (state designation 7-4, Figure 1) was pneumatically injected into an existing adit above it in winter, 1981. Subsequent seeding, fertilization and mulching occurred on the disturbed area. Topsoil acquired from the James Milo ranch was pneumatically applied at a depth of 4-6 inches to the surface of the area left after the mine waste pile was eliminated. The topsoil contained sufficient moisture to offer adequate compaction to prevent downhill movement; no seedbed preparation was necessary. Fertilizer (18-46-0) and straw mulch were applied in April at the rate of 300 lbs/acre and 1000 lbs., respectively.

The seeding mixture and rate of application appear below:

Agropyron spicatum/bluebunch wheatgrass	6 lbs/acre
Agroyron dasytachyum/thickspike wheatgrass	5 lbs/acre
Agropyron smithii/western wheatgrass	5 lbs/acre
Agropyron trachycaulum/slender wheatgrass	7 lbs/acre
Medicago sativa/alfalfa	3 lbs/acre
Stipa viridula/green needlegrass	4 lbs/acre
Triticum aestivum/winter wheat	5 lbs/acre

Fig. 1. Armington pneumatic injection demonstration site, fall, 1980.

The site was first assessed for revegetation success in June. Seedlings appeared to be well established and were achieving a good rate of growth. Plant vigor was demonstrated by relatively long seedling leaf length and a reasonably high number of seedheads. The straw mulch offered good protection for the smaller seedlings and for the soil; there was little sign of soil movement (see Figure 2).

Fig. 2. Armington pneumatic injection demonstration site, spring, 1981.

The site was re-examined and sampled in September. Grazing utilization was approximately 65 percent. Plants were clipped down to the ground surface or pulled out by the roots. Few, if any seedheads were visible to aid in the identification of certain graminoids. Much of the straw mulch was missing and bare ground was evident throughout the reclaimed area (see Figures 3 and 4).

Fig. 3. Armington pneumatic injection demonstration site, summer, 1981.

Fig. 4. Seedling establishment as affected by grazing pressure, Armington pneumatic injection demonstration site, summer, 1981.

Canopy coverage data was collected from two parallel 20 m transects placed 10 m apart on the contour of the hillside. Percent canopy coverage and frequency of occurrence was estimated by placing twenty (20) 2 x 5 dm Daubenmire frames at 2 m intervals along the transects.

The following results were obtained: bare ground, 26.7 percent cover; rock, 14.0 percent cover; and litter, 56.3 percent cover. There were no lichens or mosses, which is to be expected on a recently reclaimed site. The somewhat high 56.3 percent coverage by litter could be attributed to the straw mulch and large number of uprooted plants.

Sampling resulted in establishing the vegetation type of the site as thickspike and slender wheatgrass/winter wheat. (The two wheatgrasses, slender and thickspike, were considered cumulatively as <u>Agropyron caninum</u>, after Hitchcock.). The combined wheatgrasses accounted for 11.1 percent coverage; winter wheat was 4.7 percent. Cheatgrass brome (<u>Bromus tectorum</u>) was a healthy annual competitor at 4.6 percent coverage, while the remaining seeded grass species comprised an average two to three percent each.

Alfalfa appeared somewhat dwarfed in size and had a coverage of 6.7 percent. A small number of "weedy" species accounted for the remaining forbs. Shrubs which existed prior to reclamation each comprised less than one percent canopy coverage: chokecherry (<u>Prunus virginiana</u>), Wood's rose (<u>Rosa woodsii</u>) and western snowberry (<u>Symphoricarpos occidentalis</u>).

The initial stand examination revealed a vigorous establishment of seedlings with high potential for erosion control, eventual ecosystem stability and increased production for grazing use. Ideally, the site should have been

fenced separately from the pasture below it and grazing should have been deferred until the second season of growth or later. The fact that cattle were allowed to utilize this area so early seriously jeopardizes its chances for successful establishment.

V. Additional reclamation sites

Section 13 T19 R5E contains an additional gob pile and adit found during the latter part of the Belt and Sand Coulee abandoned mine study. This particular mine is about an acre in size and is located on a hillside in the Spring Creek drainage. It is similar to the Belt and Sand Coulee mines studied earlier. Access to the mine is not difficult.

The adit is damp, evidencing past flows and should be considered for reclamation accordingly.

Sections 25, 35 and 36, T19N R4E in Number Five Coulee near Stockett contain a burning coal seam that has presently burned about a mile of underground coal. These burning seams have occasionally caused range fires, particularly during dry periods in the summer and fall.

An adequate solution for rectifying the burning is to determine the direction of the burning seam and then excavate the unburned coal in front of the fire. Without any fuel the fire should expire in a minimal amount of time. Until the fire is extinguished, a periodic monitoring program should be initiated to prevent range fires and to assure that the procedure is successful.

The southeast quarter of section 12 and the northeast quarter of section 13, T19N, R4E, contains approximately 40 acres of small grain cropland in an 80 acre enclosure owned by Renee Lynch and leased by Charlee Srantizk. This

field has been damaged by coal from gob piles located in an adjacent coulee. Past flooding incidents have transported the coal from the upper part of the coulee and deposited it in the field downstream. Damage varies from no vegetation in part of the field (40 acres) to sparse and stunted vegetation on the remaining 40 acres.

An intense soil testing, liming and fertilization program is recommended to mitigate the damaged section of the field. Soil tests should be conducted on the remining 40 acres to determine appropriate fertilization and/or liming rates.

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VII. Appendices

Appendix A. Chemical properties of survey material by site, Belt-Sand Coulee area, Montana, 1980.

Table 1 Chemical Properties of Survey Material. Westech. 10/80.

Lab No.	Depth inches	pH Paste	Sat'n. %	Saturation Extract: Elect. Cond. mmhos/cm	Cations Ca (meq/liter)	Mg	Na	SAR
S-1A								
851	0-6	6.9	42.7	0.90	8.48	1.33	0.93	0.42
852	6-12	7.1	38.2	0.53	4.98	0.87	0.93	0.54
853	12-27	7.2	34.8	0.59	4.20	0.87	0.93	0.58
857	27-33	7.3	30.7	0.60	3.81	1.79	0.93	0.56
S-1D								
845	0-6	3.5	46.5	1.38	10.81	4.99	1.51	0.54
846	6-12	7.1	38.5	2.60	34.83	20.52	1.86	0.35
847	12-30	4.8	42.0	1.95	23.17	13.64	1.86	0.43
848	30-48	7.2	40.3	2.75	27.07	31.97	1.86	0.34
S-14								
2244	0-6	7.3	36.0	0.70	5.37	2.25	0.93	0.48
2245	6-12	7.6	31.2	0.53	4.59	1.55	0.93	0.53
2246	12-18	7.7	32.3	0.60	5.75	2.25	0.93	0.46
2247	18-42	7.8	30.6	0.58	4.20	2.25	0.93	0.52
2248	42-66	7.9	31.0	0.52	4.20	1.79	0.93	0.54
2249	66-92	7.9	25.2	0.63	4.59	2.25	0.93	0.50
S-16								
2255	0-6	5.0	39.3	0.45	3.03	1.33	1.51	1.02
2256	6-12	5.0	33.3	0.28	2.26	0.87	0.93	0.74
2257	12-20	5.5	33.5	0.31	2.26	1.10	0.93	0.72
S-18								
2263	0-6	5.5	33.6	0.46	3.03	2.25	0.93	0.57
2264	6-12	5.8	31.7	0.35	2.64	1.55	0.93	0.64
2265	12-18	6.4	31.5	0.52	3.81	1.79	0.93	0.56
S-21								
3683	0-6	6.7	49.6	1.58	9.38	3.46	4.67	1.84
3684	6-12	6.9	42.8	0.86	4.94	2.55	2.26	1.17
3685	12-18	7.6	32.0	0.87	4.94	2.30	1.78	0.94
3686	18-30	7.3	30.6	1.34	9.93	4.36	2.48	0.93

Table 2 Results of Mechanical Analysis(Hydrometer Method) with NO3 and Boron for Survey Material. Westech. 10/80.

Lab No.	Depth inches	Mechanical Analysis Sand %	Clay %	Silt %	Texture	NO3 ppm	B ppm
S-1A							
851	0-6	40.4	33.2	26.4	Cl	0.3	1.9
852	6-12	22.4	45.6	32.0	C	1.0	0.7
853	12-27	18.4	45.6	36.0	C	0.7	0.3
857	27-33	14.4	50.0	35.6	C	0.7	0.5
S-1D							
845	0-6	62.4	10.0	27.4	Sl	0.7	2.2
846	6-12	52.4	16.0	31.6	Sl	0.3	0.3
847	12-30	48.4	12.0	39.6	L	2.0	1.4
848	30-48	46.4	23.2	30.4	L	1.0	1.6
S-14							
2244	0-6	26.8	37.6	35.6	Cl	0.1	-0.1
2245	6-12	68.0	11.6	20.4	Sl	0.1	-0.1
2246	12-18	65.2	18.0	16.8	Sl	0.1	0.1
2247	18-42	59.2	18.0	22.8	Sl	0.1	-0.1
2248	42-66	56.8	19.6	23.6	Sl	0.1	-0.1
2249	66-92	53.2	23.6	23.2	SCL	0.1	-0.1
S-16							
2255	0-6	52.4	2.76	20.0	SCL	0.1	-0.1
2256	6-12	41.2	32.0	26.8	CL	0.1	-0.1
2257	12-20	31.2	8.0	60.8	SiL	0.1	0.2
S-18							
2263	0-6	63.2	18.4	18.4	Sl	0.7	0.1
2264	6-12	38.0	34.8	27.2	Cl	0.3	-0.1
2265	12-18	33.6	40.8	25.6	C	0.7	-0.1
S-21							
3683	0-6	50.0	21.2	28.8	L	8.0	0.4
3684	6-12	53.2	25.2	21.6	SCL	9.0	0.3
3685	12-18	67.2	17.6	15.2	Sl	6.0	-0.1
3686	18-30	64.4	20.0	15.6	Sl	8.0	-0.1

Table 3 Chemical Properties of Overburden Material. Westech. 10/80.

Lab No.	Depth inches	pH Paste	Sat'n. %	Saturation Extract: Elect. Cond. mmhos/cm	Cations: Ca	Mg	Na	SAR
					- - - meq/liter- - -			
S-1B								
849	0-6	2.2	37.7	4.70	26.85	6.66	4.65	1.14
850	6-12	1.8	33.5	4.10	26.85	5.51	4.65	1.16
1299	12-20	3.5	32.5	4.00	22.95	7.77	4.65	1.19
1300	20-26	5.2	32.3	2.40	24.73	10.45	1.86	0.44
1301	26-48	7.2	34.3	2.30	20.85	13.64	1.86	0.45
S-1C								
854	0-6	5.5	25.3	1.50	28.68	6.60	0.93	0.29
855	0-6	2.5	30.9	0.49	3.03	1.10	0.93	0.65
856	6-48	2.9	33.1	0.65	4.98	1.10	0.93	0.53
S-1D								
846	6-12	7.1	38.5	2.60	34.83	20.52	1.86	0.35
S-2A								
1303	0-6	2.5	33.5	1.30	6.92	4.99	0.93	0.41
1304	6-12	2.4	30.3	1.05	6.92	1.79	0.93	0.45
1305	12-18	2.1	32.3	1.12	5.37	1.79	1.32	0.70
1306	18-34	2.5	36.5	2.12	18.51	3.57	1.86	0.56
S-2B								
1307	0-6	3.2	38.3	0.72	5.75	1.10	0.93	0.50
1308	6-12	3.7	43.3	0.68	5.37	1.79	0.93	0.49
1309	12-18	6.5	39.8	1.15	10.03	2.93	1.70	0.67
1310	18-30	7.4	31.7	1.18	9.26	2.93	0.93	0.38
S-2C (Cinder Pile)								
1302		1.8	31.4	30.00	6.85	9.53	1.86	0.65
S-3A (Cinder Pile Bottom)								
1814	0-11	6.0	36.8	2.90	28.62	18.69	1.86	0.38
1815	11-16	7.0	29.1	2.40	27.84	20.52	1.86	0.38
1816	16-30	7.3	29.0	2.40	25.51	19.60	1.86	0.39
1817	20-44	7.7	27.3	1.60	14.62	13.64	1.86	0.49
1818	40-53	7.1	32.9	1.80	13.84	11.35	2.63	0.74
S-3B (Cinder Pile)								
1813	8'	3.0	40.1	27.00	11.28	45.57	4.65	0.87
S-4A								
1819	0-6	1.9	44.9	4.20	24.90	18.10	4.65	1.00
1820	6-12	2.7	34.3	3.20	20.85	15.02	1.86	0.44
1821	12-18	2.6	29.5	4.00	15.17	12.38	4.65	1.25
1822	18-42	2.4	37.4	3.90	17.12	12.38	4.65	1.21

Table 3 Chemical Properties of Overburden Material (continued)

Lab No.	Depth inches	pH Paste	Sat'n. %	Saturation Extract: Elect. Cond. mmhos/cm	Cations: Ca	Mg	Na	SAR
					- - -meq/liter- - -			
S-5A								
1992	0-6	3.4	37.3	1.34	13.84	4.03	1.86	0.62
1832	6-12	3.2	55.5	0.99	6.14	2.02	0.93	0.46
1833	12-18	3.4	52.7	1.06	7.62	2.67	1.86	0.82
1834	18-40	3.2	26.3	2.45	33.28	5.86	1.86	0.42
S-6								
1993	0-6	3.2	24.6	1.00	6.14	2.25	0.93	0.45
S-7A								
1823	0-6	2.4	38.1	8.00	19.06	101.64	4.65	0.60
S-8 (Cinder)								
1994	6'	1.9	44.8	20.00	0.80	9.46	7.72	3.41
S-9								
1830	0-6	3.5	46.3	3.00	17.73	14.10	1.86	0.47
1831	6-12	3.4	48.2	2.90	30.18	10.89	1.86	0.41
1995	12-18	3.4	56.6	2.30	21.62	6.78	1.86	0.49
1996	18-39	4.5	39.9	2.60	23.17	22.34	1.86	0.39
S-10								
1997	0-6	3.1	32.8	3.60	18.51	19.60	1.86	0.43
1827	6-12	3.0	28.1	4.60	19.06	31.84	4.65	0.92
1828	12-18	2.8	27.5	5.00	17.12	27.23	4.65	0.99
1829	18-27	2.7	29.2	6.00	19.06	36.40	4.65	0.88
S-11								
1998	0-6	2.3	41.7	7.00	30.71	38.71	4.65	0.79
1824	6-12	2.2	40.9	7.00	21.01	19.25	4.65	1.04
1825	12-18	2.2	40.1	6.60	21.01	15.79	4.65	1.08
1999	18-48	2.5	41.6	5.00	17.12	14.64	4.65	1.17
2000	48-65	2.7	38.0	3.30	13.06	10.45	1.86	0.54
S-12								
1826	0-6	2.2	46.5	5.20	11.28	19.25	4.65	1.19
2001	6-12	2.3	32.9	5.20	13.22	23.82	4.65	1.08
2002	12-26	2.1	33.0	6.40	13.22	24.97	4.65	1.06
S-13								
2239	0-6	3.7	34.5	1.90	16.18	10.45	1.86	0.51
2240	6-12	3.3	38.2	1.34	6.14	4.53	0.93	0.40
2241	12-18	2.6	37.5	2.80	10.74	11.35	1.86	0.56
2242	18-44	2.5	32.8	4.00	17.12	20.36	4.65	1.07
S-13B (Cinder)								
2243	6'	4.3	70.4	1.07	8.87	4.53	0.93	0.36

Table 3 Chemical Properties of Overburden Material (continued)

Lab No.	Depth inches	pH Paste	Sat'n. %	Saturation Extract: Elect. Cond. mmhos/cm	Cations Ca - - meq/liter - -	Mg	Na	SAR
S-15								
2250	0-6	2.6	37.1	0.56	3.03	1.79	0.93	0.60
2251	6-10	2.5	45.4	0.62	3.42	1.79	0.93	0.58
2252	10-18	2.6	33.7	0.55	3.03	1.10	0.93	0.65
2253	18-42	3.3	31.6	0.70	4.97	1.33	1.32	0.74
2254	42-80	7.0	35.5	0.79	4.97	1.79	2.48	1.35
S-17								
2258	0-6	2.3	58.5	6.20	19.06	69.60	8.52	1.28
2259	6-12	2.9	32.3	0.39	18.59	36.08	4.61	0.88
2260	12-18	3.3	31.0	4.00	22.95	45.57	6.59	1.13
2261	18-44	7.8	33.7	2.70	6.07	31.97	7.67	1.76
2262	44-78	7.7	27.3	1.94	6.07	26.92	3.02	0.74
S-19								
3674	0-6	3.9	43.1	1.04	6.04	6.04	3.47	1.70
3675	6-12	3.8	40.6	0.96	5.44	2.30	2.99	1.52
3676	12-18	4.2	46.1	0.94	5.44	2.06	4.67	2.41
3677	18-42	7.2	43.8	1.00	8.53	3.21	3.71	1.53
3678	42-60	7.1	38.0	0.90	7.14	2.96	2.27	1.01
S-20								
3679	0-6	4.5	34.6	0.59	4.39	1.89	1.54	0.87
3680	6-12	3.0	37.7	0.62	3.84	1.40	1.30	0.80
3681	12-18	2.5	39.1	2.85	67.61	2.80	1.54	0.26
3682	18-34	4.9	39.4	2.10	39.30	6.91	1.07	0.22
S-22								
3687	0-12	3.6	37.8	9.60	1.12	2.47	6.52	4.87
S-23								
3688	0-6	2.9	43.8	2.80	11.58	13.33	1.78	0.50
3689	6-12	3.8	39.7	2.80	74.35	12.83	1.30	0.20
3690	12-18	5.2	35.1	2.90	68.86	16.95	1.78	0.27
3691	18-42	7.6	35.9	2.40	31.69	16.95	2.02	0.41
S-24								
3692	0-6	6.9	46.3	0.90	8.23	3.46	4.43	1.83
3693	6-12	7.3	44.9	0.88	11.03	2.30	2.02	0.78
3694	12-18	7.6	44.2	0.55	5.74	1.65	2.26	1.18
3695	18-42	7.9	40.7	0.60	4.64	2.30	2.48	1.33
3696	42-72	8.1	31.1	0.60	2.99	3.70	2.48	1.36

Table 4 Results of Mechanical Analysis (Hydrometer Method) with NO3, Exchangeable NH4 and Boron for Overburden Material. Westech. 10/80.

Lab No.	Depth inches	Mechanical Analysis Sand %	Clay %	Silt %	Texture	NO3 ppm	Exch. NH4 ppm	B ppm
S-1B								
849	0-6	26.4	2.0	71.6	SiL	0.3	27.3	2.5
850	6-12	56.4	5.2	38.4	SL	0.1	25.6	2.5
1299	12-20	50.4	6.0	43.6	SL	0.3	19.5	0.7
1300	20-26	50.4	6.0	43.6	SL	0.1	19.5	0.7
1301	26-48	32.4	26.0	41.6	CL	2.0	20.1	0.7
S-1C								
854	0-6	66.4	12.0	21.6	SL	4.0	20.2	0.7
855	0-6	58.4	22.0	19.6	SCL	1.0	19.4	1.9
856	6-48	64.4	16.0	19.6	SL	0.1	19.7	0.7
S-1D								
846	6-12	52.4	16.0	31.6	SL	0.3	17.1	0.3
S-2A								
1303	0-6	32.4	30.0	37.6	CL	+50.0	19.8	1.2
1304	6-12	40.4	23.2	36.4	L	13.0	20.2	0.7
1305	12-18	34.4	31.6	34.0	C	11.0	20.1	0.7
1306	18-34	28.4	43.6	28.0	C	7.0	20.1	0.3
S-2B								
1307	0-6	30.4	43.2	26.4	C	3.0	20.2	0.3
1308	6-12	31.2	41.2	27.6	C	2.0	20.0	0.3
1309	12-18	31.2	39.2	29.6	CL	1.0	20.3	0.3
1310	18-30	35.2	33.2	31.6	CL	1.0	19.8	0.3
S-2C (Cinder Pile)								
1302		26.4	20.0	53.6	SiL	32.0	20.2	10.3
S-3A (Cinder Pile Bottom)								
1814	0-11	37.6	31.2	31.2	CL	3.0	11.9	2.8
1815	11-16	42.0	33.2	24.8	CL	3.0	15.3	0.3
1816	16-30	40.0	21.2	38.8	L	6.0	13.6	0.3
1817	20-44	51.2	21.2	27.6	SCL	8.0	18.7	0.7
1818	40-53	27.2	30.0	42.8	CL	4.0	23.9	0.7
S-3B (Cinder Pile)								
1813	8'	41.2	31.2	31.2	CL	2.0	20.5	10.5
S-4A								
1819	0-6	71.2	10.0	18.8	SL	2.0	25.6	0.3
1820	6-12	82.0	8.0	10.0	SL	3.0	27.3	0.3
1821	12-18	57.2	20.0	22.8	SCL	1.0	44.3	0.5
1822	18-42	38.0	8.0	54.0	SiL	1.0	30.7	0.7

Table 4 Results of Mechanical Analysis (Hydrometer Method) with NO3, Exchangeable NH4 and Boron for Overburden Material. (continued)

Lab No.	Depth	Mechanical Analysis Sand %	Clay %	Silt %	Texture	NO3 ppm	NH4 ppm	B ppm
S-5A								
1992	0-6	64.0	11.2	24.8	SL	2.0	17.1	0.6
1832	6-12	61.2	10.0	28.8	SL	6.0	15.3	0.5
1833	12-18	63.6	8.0	28.4	SL	4.0	18.8	0.3
1834	18-40	54.0	23.2	22.8	SCL	4.0	17.1	0.3
S-6								
1993	0-6	65.6	11.2	23.2	SL	2.0	22.2	0.3
S-7A								
1823	0-6	50.8	1.6	47.6	SL	0.7	42.6	1.6
S-8 (Cinder)								
1994	6'	34.0	11.2	54.8	SiL	2.0	17.1	0.18
S-9								
1830	0-6	17.6	50.0	32.4	C	9.0	63.1	0.5
1831	6-12	13.6	26.0	60.4	SiL	6.0	39.2	0.3
1995	12-18	10.4	15.2	74.4	SiL	4.0	20.5	1.3
1996	18-39	41.6	5.2	53.2	SiL	3.0	15.3	1.3
S-10								
1997	0-6	34.0	7.2	58.8	SiL	3.0	39.0	2.2
1827	6-12	51.2	6.0	42.8	SL	3.0	32.4	0.3
1828	12-18	47.6	4.0	48.4	SL	2.0	27.3	0.3
1829	18-27	55.6	4.0	40.4	SL	1.0	34.1	0.3
S-11								
1998	0-6	14.4	7.2	78.4	SiL	2.0	22.2	2.2
1824	6-12	17.2	11.6	71.2	SiL	2.0	25.6	0.7
1825	12-18	21.6	7.2	71.2	SiL	2.0	20.5	0.3
1999	18-48	16.8	21.2	62.0	SiL	3.0	17.1	2.2
2000	48-65	24.4	5.2	70.4	SiL	2.0	3.4	2.2
S-12								
1826	0-6	35.2	2.0	62.8	SiL	3.0	83.6	0.3
2001	6-12	34.8	5.2	60.0	SiL	2.0	42.6	1.3
2002	12-26	50.8	3.2	46.0	SL	1.0	30.7	1.3
S-13								
2239	0-6	36.8	25.2	38.0	CL	0.7	3.4	0.3
2240	6-12	32.8	29.2	38.0	CL	2.0	6.3	1.3
2241	12-18	58.8	10.8	30.4	SL	0.1	25.6	0.7
2242	18-44	51.2	21.2	27.6	SCL	0.1	15.3	0.9
S-13B (Cinder)								
2243	6'	44.2	17.4	38.4	L	2.0	11.9	0.4

Table 4 Results of Mechanical Analysis (Hydrometer Method) with NO3, Exchangeable NH4 and Boron for Overburden Material. (continued)

Lab No.	Depth inches	Mechanical Analysis Sand %	Clay %	Silt %	Texture	NO3 ppm	NH4 ppm	B ppm
S-15								
2250	0-6	70.0	17.2	12.8	SL	1.0	34.1	0.25
2251	6-10	64.0	13.2	22.8	SL	8.0	14.5	0.10
2252	10-18	80.0	13.2	6.8	SL	2.0	9.4	0.10
2253	18-42	36.0	27.2	36.8	CL	2.0	12.4	0.10
2254	42-80	32.0	23.2	44.8	L	4.0	2.5	0.10
S-17								
2258	0-6	53.2	20.8	26.0	SCL	2.6	93.3	0.25
2259	6-12	44.0	24.4	31.6	L	11.0	30.3	0.25
2260	12-18	48.0	24.4	27.6	L	12.0	8.5	0.30
2261	18-44	52.0	24.4	23.6	SCL	8.0	3.4	5.50
2262	44-78	51.6	20.4	28.0	SCL	3.0	3.6	0.75
S-19								
3674	0-6	78.0	10.4	11.6	SL	42.0	8.5	0.10
3675	6-12	58.8	18.4	22.8	SL	13.0	6.8	0.10
3676	12-18	80.8	10.4	8.8	LS	13.0	8.5	0.10
3677	18-42	53.6	26.4	20.0	SCL	18.0	6.8	0.25
3678	42-60	50.8	22.4	26.8	SCL	11.0	3.4	0.75
S-20								
3679	0-6	65.0	14.4	20.6	SL	9.0	5.1	0.10
3680	6-12	82.0	11.2	6.8	LS	3.0	3.4	0.10
3681	12-18	55.2	3.6	41.2	SL	2.0	10.2	0.10
3682	18-34	59.2	11.6	29.2	SL	3.0	11.9	0.10
S-22								
3687	0-12	48.0	7.0	45.0	L	5.0	5.1	1.10
S-23								
3688	0-6	63.2	20.8	16.0	SCL	15.0	107.4	0.45
3689	6-12	43.2	27.2	29.6	CL	10.0	80.1	0.25
3690	12-18	45.6	5.6	48.8	SL	17.0	40.9	0.10
3691	18-42	39.6	28.8	31.6	CL	13.0	3.4	0.10
S-24								
3692	0-6	59.2	20.4	20.4	SCL	1.0	3.4	0.10
3693	6-12	36.8	28.0	35.2	CL	3.0	3.4	0.10
3694	12-18	43.6	28.0	28.4	CL	0.7	3.4	0.10
3695	18-42	49.2	21.6	29.2	L	0.3	3.4	0.40
3696	42-72	21.2	37.6	41.2	CL	0.7	3.4	0.25

Table 5 Chemical Properties of Overburden Material. Westech. 10/80.

Depth inches	Ni ppm	Cd ppm	Pb ppm	Zn ppm	Fe ppm	Cu ppm	Mn ppm	Hg ppb	Mo ppm	Se ppm
S-1B										
0-6	-0.10	-0.1	-0.10	-0.02	180.0	0.28	4.0	12	0.24	-0.5
6-12	-0.10	-0.1	-0.10	-0.02	163.8	-0.20	29.0	12	3.30	-0.5
12-20	-0.10	-0.1	-0.10	-0.02	117.6	-0.20	16.8	8	2.57	-0.5
20-26	-0.10	-0.1	-0.10	-0.02	12.0	0.50	8.4	8	0.46	-0.5
26-48	-0.10	-0.1	-0.10	-0.02	4.8	0.28	9.2	12	0.23	-0.5
S-1C										
0-6	-0.10	-0.1	-0.10	0.02	27.6	0.36	6.7	316	0.96	-0.5
0-6	-0.10	-0.1	-0.10	-0.02	150.0	0.14	1.4	96	0.46	-0.5
6-48	-0.10	-0.1	-0.10	-0.02	84.6	0.50	2.8	94	0.46	-0.5
S-1D										
6-12	1.72	-0.1	-0.10	2.50	158.4	1.80	6.0	36	1.42	-0.5
S-2A										
0-6	-0.10	-0.1	-0.10	2.16	50.4	0.92	10.8	36	2.05	-0.5
6-12	-0.10	-0.1	-0.10	0.08	288.0	2.66	12.0	36	2.05	-0.5
12-18	-0.10	-0.1	-0.10	-0.02	204.0	2.16	13.4	36	-0.33	-0.5
18-34	-0.10	-0.1	-0.10	-0.02	63.6	2.22	6.0	32	-0.33	-0.5
S-2B										
0-6	-0.10	-0.1	-0.10	-0.02	29.4	0.92	7.2	56	-0.33	-0.5
6-12	-0.10	-0.1	-0.10	-0.02	24.0	1.20	8.4	54	-0.33	-0.5
12-18	-0.10	-0.1	-0.10	-0.02	6.0	0.50	6.7	66	-0.33	-0.5
18-30	-0.10	-0.1	-0.10	-0.02	0.0	0.28	1.2	80	-0.33	-0.5
S-2C (Cinder Pile)										
	14.40	-0.1	-0.10	6.0	1392.0	4.70	+30.0	8	1.19	-0.5
S-3A (Cinder Pile Bottom)										
0-11	-0.10	-0.1	-0.10	-0.02	15.6	0.14	0.6	8	-0.33	-0.5
11-16	-0.10	-0.1	-0.10	-0.02	8.4	-0.02	24.0	8	-0.33	-0.5
16-30	-0.10	-0.1	-0.10	-0.02	4.8	-0.02	21.0	8	-0.33	-0.5
20-44	-0.10	-0.1	-0.10	-0.02	6.0	1.44	4.8	18	-0.33	-0.5
40-53	-0.10	-0.1	-0.10	-0.02	2.0	1.30	3.4	12	-0.33	-0.5
S-3B (Cinder Pile)										
8'	3.80	-0.1	-0.10	3.68	189.6	0.42	6.0	-4	1.91	-0.5
S-4A										
0-6	-0.10	-0.1	-0.10	0.08	150.0	0.72	9.5	134	1.30	-0.5
6-12	-0.10	-0.1	-0.10	-0.02	150.0	0.42	4.8	102	1.30	-0.5
12-18	-0.10	-0.1	-0.10	-0.02	240.0	0.86	2.8	72	0.23	-0.5
18-42	-0.10	-0.1	-0.10	-0.02	180.0	0.02	10.0	46	1.06	-0.5

Table 5 Chemical Properties of Overburden Material. Westech. 10/80. (continued)

Depth inches	Ni ppm	Cd ppm	Pb ppm	Zn ppm	Fe ppm	Cu ppm	Mn ppm	Hg ppb	Mo ppm	Se ppm
S-5A										
0-6	-0.1	-0.1	-0.1	-0.02	45	1.28	8.6	72	1.0	-0.5
6-12	-0.1	-0.1	-0.1	-0.02	71.4	1.08	3.2	56	0.96	-0.5
12-18	-0.1	-0.1	-0.1	-0.02	55.8	1.14	3.6	46	2.51	-0.5
18-40	-0.1	-0.1	-0.1	-0.02	189.6	1.86	9.2	34	1.16	-0.5
S-6										
0-6	-0.1	-0.1	-0.1	-0.02	124.8	0.58	8.9	84	0.33	-0.5
S-7A										
0-6	-0.1	-0.1	-0.1	2.22	199.2	0.14	21.6	2	0.76	-0.5
S-8										
6'	9.17	-0.1	-0.1	3.1	996.0	15.80	86.0	900	1.09	-0.5
S-9										
0-6	-0.1	-0.1	-0.1	2.88	54.0	2.58	8.2	34	0.33	-0.5
6-12	-0.1	-0.1	-0.1	1.28	43.2	2.76	4.4	20	0.46	-0.5
12-18	-0.1	-0.1	-0.1	0.86	55.8	2.16	6.2	8	0.56	-0.5
18-39	-0.1	0.81	-0.1	2.88	0.0	0.36	16.2	166	0.56	-0.5
S-10										
0-6	0.25	-0.1	-0.1	0.64	147.6	1.14	0.6	64	0.56	-0.5
6-12	-0.1	-0.1	-0.1	0.72	151.2	1.20	0.6	38	0.33	-0.5
12-18	-0.1	-0.1	-0.1	0.50	160.8	0.86	28.0	84	0.63	-0.5
18-27	-0.1	-0.1	-0.1	0.28	180.0	0.50	6.0	56	0.33	-0.5
S-11										
0-6	-0.1	-0.1	-0.1	5.2	166.8	0.14	13.4	188	1.09	-0.5
6-12	-0.1	-0.1	-0.1	1.0	158.0	-0.02	8.6	54	1.29	-0.5
12-18	-0.1	-0.1	-0.1	1.0	180.0	-0.02	7.0	80	1.29	-0.5
18-48	-0.1	-0.1	-0.1	2.5	180.0	1.64	6.4	34	-0.33	-0.5
48-65	0.77	-0.1	-0.1	2.5	172.8	1.50	6.7	12	0.56	-0.5
S-12										
0-6	-0.1	-0.1	-0.1	0.02	235.2	-0.02	9.5	30	0.56	-0.5
6-12	-0.1	-0.1	-0.1	-0.02	199.0	-0.02	6.7	80	0.56	-0.5
12-26	-0.1	-0.1	-0.1	0.14	0.99	-0.02	8.6	32	0.33	-0.5
S-13										
0-6	-0.1	-0.1	-0.1	0.11	157.0	0.14	3.2	268	4.3	-0.5
6-12	-0.1	-0.1	-0.1	-0.02	81.0	-0.02	1.0	213	0.26	-0.5
12-18	-0.1	-0.1	-0.1	-0.02	360.0	0.14	1.8	272	0.39	-0.5
18-44	-0.1	-0.1	-0.1	-0.02	199.0	-0.02	9.2	12	0.53	-0.5
S-13B (Cinder)										
6'	-0.1	-0.1	-0.1	3.7	1105.0	6.1	0.6	38	0.10	-0.5

Table 5 Chemical Properties of Overburden Material. Westech. 10/80. (continued)

Depth inches	Ni ppm	Cd ppm	Pb ppm	Zn ppm	Fe ppm	Cu ppm	Mn ppm	Hg ppb	Mo ppm	Se ppm
S-15										
0-6	-0.1	-0.1	-0.1	-0.02	194.0	5.42	6.4	204	0.92	-0.5
6-10	-0.1	-0.1	-0.1	-0.02	180.0	12.0	3.2	54	0.26	-0.5
10-18	-0.1	-0.1	-0.1	-0.02	295.0	53.6	5.2	72	1.19	-0.5
18-42	-0.1	-0.1	-0.1	4.04	198.0	28.0	12.4	96	0.33	-0.5
42-80	-0.1	-0.1	-0.1	-0.02	4.8	1.36	11.4	34	0.79	-0.5
S-17										
0-6	0.12	-0.1	-0.1	0.20	177.6	1.20	64.8	32	0.79	-0.5
6-12	-0.1	-0.1	-0.1	-0.02	120.0	1.00	45.6	94	0.79	-0.5
12-18	0.25	-0.1	-0.1	-0.02	34.8	0.78	26.4	20	0.66	-0.5
18-44	-0.1	-0.1	-0.1	-0.02	4.8	0.20	5.4	32	0.43	-0.5
44-78	-0.1	-0.1	-0.1	-0.02	4.8	0.28	6.4	12	1.80	-0.5
S-19										
0-6	-0.1	-0.1	-0.1	1.72	0.72	1.28	4.0	144	0.11	-0.5
6-12	-0.1	-0.1	-0.1	1.86	139.2	3.90	1.8	225	0.08	-0.5
12-18	-0.1	-0.1	-0.1	1.50	105.6	2.76	3.2	100	0.11	-0.5
18-42	-0.1	-0.1	-0.1	3.54	6.0	1.08	3.4	46	0.39	-0.5
42-60	-0.1	-0.1	-0.1	0.64	4.8	0.86	2.8	38	0.17	-0.5
S-20										
0-6	-0.1	-0.1	-0.1	0.36	71.4	0.20	0.1	134	0.26	-0.5
6-12	-0.1	-0.1	-0.1	0.14	55.8	0.14	0.1	134	0.79	-0.5
12-18	-0.1	-0.1	-0.1	0.14	169.2	0.14	0.1	664	0.71	-0.5
18-34	-0.1	-0.1	-0.1	5.80	194.4	0.42	5.4	38	0.17	-0.5
S-22										
0-12	-0.1	-0.1	-0.1	0.92	13.2	-0.02	4.2	66	0.17	-0.5
S-23										
0-6	-0.1	-0.1	-0.1	0.72	258.0	1.20	7.4	96	0.41	-0.5
6-12	-0.1	-0.1	-0.1	0.28	247.1	0.78	6.2	56	0.08	-0.5
12-18	-0.1	-0.1	-0.1	0.58	99.6	0.50	23.2	38	0.92	-0.5
18-42	-0.1	-0.1	-0.1	-0.02	0.0	0.14	1.0	32	0.17	-0.5
S-24										
0-6	-0.1	-0.1	-0.1	1.36	22.8	0.68	3.2	102	0.26	-0.5
6-12	-0.1	-0.1	-0.1	0.28	58.8	1.00	1.4	76	0.13	-0.5
12-18	-0.1	-0.1	-0.1	0.36	0.0	0.28	0.1	46	0.33	-0.5
18-42	-0.1	-0.1	-0.1	0.08	0.0	0.28	0.1	38	0.56	-0.5
42-72	-0.1	-0.1	-0.1	0.14	0.0	0.36	0.1	38	0.33	-0.5

Appendix B. Investigation of environmental effects of abandoned coal mines in the Sand Coulee and Belt Creek drainage areas, prepared by Montana Testing Laboratories, Cascade County, Montana.

INVESTIGATION
OF
ENVIRONMENTAL EFFECTS OF ABANDONED COAL MINES IN THE SAND COULEE AND BELT CREEK DRAINAGE AREAS CASCADE COUNTY, MONTANA

MONTANA TESTING LABORATORIES, INC.
GREAT FALLS, MONTANA

Raymond T. Choriki, Soils Specialist
Fred Sandoval, Consultant

TITLE:

Investigation of Environmental Effects of Abandoned Coal Mines in the Sand Coulee and Belt Creek Drainage areas, Cascade County, Montana.

LOCATION:

Sand Coulee and Belt, Montana

DATE INITIATED:

Sample Collection Completed:	October 31, 1980
Laboratory Analyses Completed:	February 28, 1981
Greenhouse Study Completed:	May 30, 1981
Report Completed:	July 1, 1981

SUMMARY:

1. Soil from abandoned mines and farm fields affected by mines were collected from 32 sites. They are as follows:
   A. Soil horizon samples taken from farm sites include: S-1A, S-1D, S-14, S-16, S-18, and S-21.
   B. Spoil or dump areas are: S-1B, S-1C, S-1D, S-2A, S-2B, S-2C(cinder), S-3A, S-3B(cinder pile), S-4A, S-5A, S-6, S-7A, S-8(cinder), S-9, S-10, S-11, S-12, S-13, S-13B(cinder), S-15, S-17, S-19, S-20, S-22, S-23, and S-24.

2. Samples were collected to determine toxic materials which may restrict plant growth and development or chemicals that may affect the physical properties of the soil and cause crusting or low hydraulic conductivities.

3. Significant findings from farm sites and spoils or dump sites are:

   A. Natural Sites

      1. S-1A, S-14, S-18, and S-21

      There are no chemical or physical limitations to restrict plant growth and development.

      2. S-1D

      pH is extremely acid (3.5)(Table 1) on the surface 0-6" depth which appears to be contaminated from runoff. Vegetation is present in the field, and appears to be doing very well. (See note from D. Noel) Greenhouse study indicates normal growth without additional lime. The reason for this appears to be that the low pH is due to runoff of slag into this field. The alluvium material contained very little soluble metal and has been plowed in with the subsoil in the past which would dilute the metals present.

      3. S-16

      Although the pH was slightly acid (5.0) vegetation present appears to be normal. The greenhouse study of site S-16 did not indicate any problems related to toxicity from any elements. This area with proper fertilization should produce forages without any complications.

B. Spoils or Dump Sites

As required by the State, spoils and overburden material have to be evaluated for the following parameters:

1. water soluble calcium magnesium, sodium, pH, sodium adsorption ratio, conductivity, and saturation percentage from saturated paste and extracts.
2. DTPA extractable zinc, copper, manganese, iron, nickel, lead, and cadmium.
3. hot water soluble boron and selenium.
4. arsenic, mercury and molybdenum.

The results of these analyses were used to evaluate the problems associated with spoils or dumpsite for reclamation purposes.

Results:

Soluble salts were present on sites: S-2C(cinder pile), S-3B(cinder pile), S-7A, S-8(cinder pile), S-10, S-11, S-12, S-17, and S-22 (cinder pile).

Site 2-C(cinder pile)contained high levels of DTPA extractable iron, and manganese, high boron, and excessive levels of soluble salts (Tables 3,4,&5). Vegetation will be completely absent and amendments will not correct the problem unless the soluble salts are leached out. The DTPA extractable manganese, copper and nickel are also very high but could be neutralized with lime. This cinder pile should not be used indiscriminately because it will injure vegetation permanently (or for a very long time). May be used for road material if area is selected carefully.

Site 3-B(cinder pile) contained high soluble salts with lower amounts of DTPA extractable metals. Hot water soluble boron was very high (10 ppm) and could cause injury to vegetation for a very long period. Do not use this pile indiscriminately. Use as 2-C.

Site 7-A contained high soluble salts (8 mmhos/cm) and establishment of most forages will be restricted. These samples were taken from an area that was affected by drainage along the hillside which explains the high levels of soluble salts and low extractable metals even when the pH's were low.

Site 8 (cinder pile) contained high soluble salts (20 mmhos/cm) and high DTPA extractable nickel, iron, and manganese. Mercury was 500 ppb, designated as high for vegetation development purposes. This cinder pile should be used with same precautions as S-2C. (See Tables 3, 4 & 5)

Site S-10 soils are from an area contaminated from slag and cinder pile. Soluble salts were present but not high enough to restrict plant growth. All other chemical properties were low despite the low pH values. This site should not present any problem in establishment or production if proper fertilizer and lime are included in plan.

Site 11 soils were collected immediately below a slag pile and contained moderate levels of soluble salts. Other metals were low despite the low pH values present. With proper lime and fertilizer, vegetation could be restored.

Site 22 is a cinder pile which contained moderate amounts of soluble salts. Other trace metals were very low. This cinder pile could be used for road material without contributing soluble metals from runoff.

C. Slag Pile Sites (S-1C and S-13B)

Although pH values are very acid, trace elements and soluble salts are extremely low. This could be used for roadbed material without contributing any chemicals that would affect plant growth and development.

D. Farm Fields Affected by Runoff from Cinder or Slag Piles

Site 1-D(Table 1) contains slight levels of soluble salts but proper liming and fertilizer should maintain adequate production. pH values were alternately very acid or neutral. This did appear to affect growth in the greenhouse.

Site 2-A(Tables 3,4 & 5) Although pH was very acid, there were no soluble metals or salts present to restrict plant growth. However, addition of lime was necessary at rate of 20 T/a equivalent to restore plant growth and development. (Table 7)

S-15 (Tables 3, 4 &5) DTPA extractable copper exceeded minimum level allowed of 40 ppm at 10-18" depth. This could be corrected by addition of lime at 25 T/a and plowing it 12" and deeper if possible. Other soluble metals were low despite low pH values.

Site 17 (Tables 3,4 & 5) DTPA extractable trace elements were below critical levels to restrict plant growth and development,but addition of lime did improve the growth. The pH values were very low and indicate very acid medium. Some of these low pH values may have higher DTPA extractable aluminum which may be contributing to the problem,requiring more lime, especially on highly buffered soil. The textures on this site were sandy clay loam and loam. Low pH at lower depths in the profile may be more difficult to correct as in S-15. Plowing applied lime at deep levels would help considerably.

S-19 (Tables 3,4 & 5) pH values are very low but trace elements did not exceed levels expected to restrict plant growth. Same as S-17.

S-24 (Tables 3,4 &5) This area is limited only by fertility. This could be corrected with proper choice of forages.

E. Soils Affected by Slag or Cinder Piles (Table 6)

These include sites: S-1B, S-2B, S-3A, S-4A, S-5A, S-6, S-7A, S-9, S-10, S-11, S-12, S-13, S-20 and S-23.

Sites S-7A, S-10, S-11 and S-12 were discussed earlier.

Site 1-B soils were collected below a slag pile. pH values were very low (acid) but there were no high soluble metals or other problem related properties except soluble salts. The salts were not excessive here but may be a major contributor of problems. Correction of pH can be made by adding lime at 20 T/a. There was no barley grown without lime amendment. The addition of lime improved both establishment and development. (Table 7)

Site S-2B is a site badly affected by slag and cinder material. It is located above the grain field of S-2A. pH values are very low and strongly acid; soluble salts are very low. Trace metals are very low and should not restrict plant growth, however lime was required to restore establishment and development, at rate of 20 T/a. Again this could be related to aluminum.

Sites S-4A, S-5A, S-6, S-9, S-13 and S-23 These sites are all low in pH similar to S-2B. None of these sites contain any metals that should restrict plant growth, but without the addition of lime plants appear to grow with less vigor. The pH values are very low on the top 18-30" in most of these sites and become higher at the lower depths. This is very common with deposits of acid-containing material over the normal alluvium material. Because none of these metals are high, there is a possibility that aluminum is above the excessive limits. Unless instructed, soil will not be analyzed for aluminum. These sites could be corrected for pH by liming. The proper rates should be calculated with lime requirement test and should consider depths to be neutralized.

GREENHOUSE STUDY:

The results from the chemical analyses were used to decide the treatment necessary to evaluate the greenhouse results. The greenhouse study included using 500 grams of air-dried soil per pot with two (2) replications, alfalfa and barley as the test crops, and equivalent of 0, 10 T and 20 T/acre of lime rates to correct acidity.

The acidity levels are usually associated with higher soluble metals. These were shown in Tables 3, 4, and 5. The pH, boron, texture, SAR, conductivity and nitrates are shown in Tables 1, 2, 3, 4, and 5.

The acidity levels were separated into very acid (2-4), moderately acid (4-6), neutral and above (6-8).

The relationship of slag-soil/pH and lime requirement effect on barley response for plants grown in the greenhouse are shown in Figure 1. The dry matter production increases with higher pH values. Additions of lime have increased dry matter production considerably in the very acid soils and moderately acid soils,and none at the neutral soils.

The relationship of barley culms and dry matter per pot response to lime amendment at three acid levels are shown in Table 8.

The addition of lime to neutralize the very acid soils had favorable response as shown by culm and dry matter per pot of barley cultivar. The number of culms per pot increased by twofold in the very acid soils, 1.3 fold for the moderately acid soils, and 1.0 fold for the neutral soils. The addition of lime increased the dry matter production per pot of the very acid soils by 4.5 fold, the moderately acid soils by 1.33 fold, and 1.1 fold for the neutral soils.

GENERAL SUMMARY:

The chemical analyses and the greenhouse study show that:

1. Excessive acid contamination by slag material can be corrected with addition of lime.
2. Salinity of the materials was not related to the problems of low acidity.
3. Soluble calcium and magnesium associated with acidity was variable and not well correlated with low pH's.
4. Lime amendment improved barley and alfalfa performance on very acid and moderately acid material and not on neutral material.
5. Soluble metal associated with low pH was not significant here and because of this, aluminum (not analyzed) may be the cause of poor growth on the very acid material.
6. Cinder piles contain high soluble salt and DTPA extractable manganese, copper, and hot water soluble boron; should not be used for road material.
7. Slag pile at Belt contains very low values of salts and trace elements and could be used for road materials.

Table 6

Description of sample sites collected in the Stockett - Sand Coulee and Belt abandoned mines.

Slag pile	Cinder pile	Natural soil	Soil affected by runoff from Slag or cinder pile: Farm fields	Soil affected by runoff from Slag or cinder pile: Other soils *
S-1C	S-2C	S-1A	S-1D	S-1B
S-13B	S-3B	S-14	S-2A	S-2B
	S-8	S-16	S-15	S-3A
	S-22	S-18	S-17	S-4A
		S-21	S-19	S-5A
			S-24	S-6
				S-7A
				S-9
				S-10
				S-11
				S-12
				S-13
				S-20
				S-23

* Other soil includes soil affected or contaminated from slag pile or cinder pile but not currently farming. (For example, hillside below slag pile.)

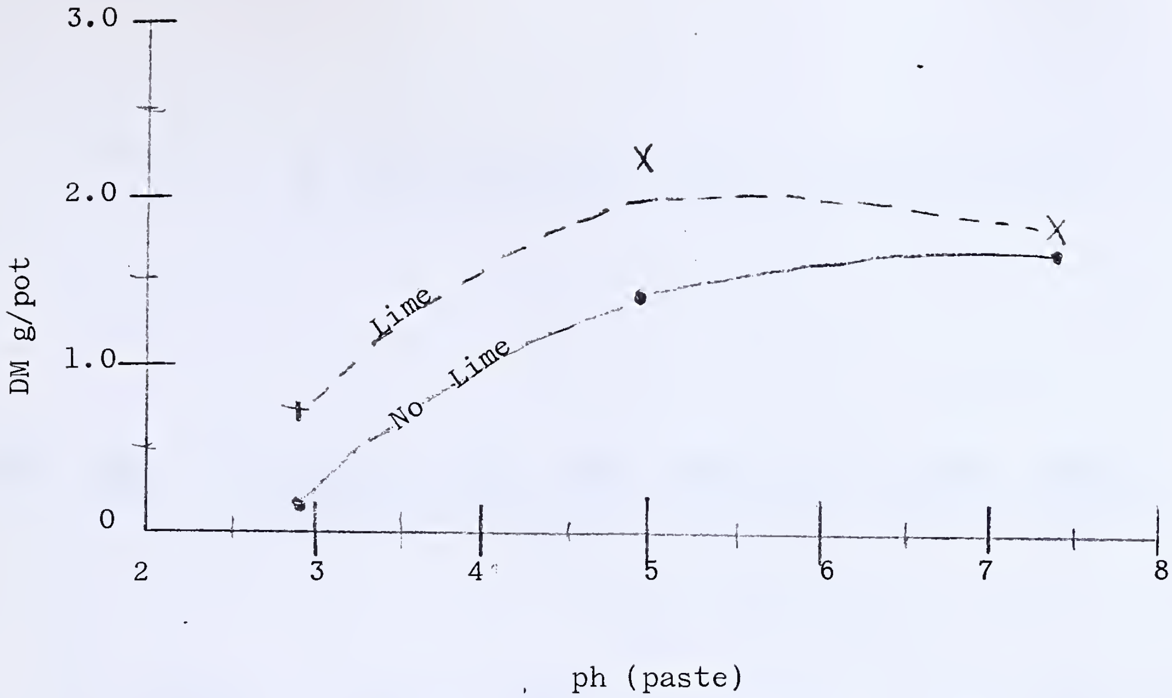

Fig. : Relative relationship of slag-soil ph and lime amendment effect on barley response for plants grown in the greenhouse.

Table: Summary of data showing barley culm response to lime amendment at three acidity levels.

	NO LIME			LIME		
Acidity, ph	culms/pot	g/culm	g/pot	culms/pot	g/culm	g/pot
2.9	4	.04	0.16	8	.09	0.72
5.0	7	.20	1.40	9	.25	2.25
7.4	13	.13	1.69	13	.14	1.82

TABLE Response of barley culms and alfalfa plants grown in the greenhouse on three acidity levels of mine slag-soil to lime amendment treatment showing response means and standard deviations.

SOIL ACIDITY	Soil site	Depth cm	ph	EC mmhos	Ca meq/le	NO LIME BARLEY culms/pot	NO LIME BARLEY g/culm	NO LIME BARLEY Ht,cm	NO LIME ALF. Ht,cm	LIME BARLEY culms/pot	LIME BARLEY g/culm	LIME BARLEY Ht,cm	LIME ALF. Ht,cm
Very acid	S-1B	0-50	2.5	4.2	25	0	0	0	0	5	.05	5	0
	S-1D	0-15	3.5	1.4	11	11	.17	51	nd	10	.20	51	nd
	S-2A	0-86	2.4	1.4	10	2	.01	4	0	5	.06	10	4
	S-5A	0-102	3.3	1.6	18	2	.01	6	0	7	.09	24	12
	S-13	0-112	3.0	2.5	12	2	tr	4	tr	8	.10	28	4
	S-17	0-45	2.8	3.5	20	6	.09	12	3	8	.11	17	5
	S-20	30-45	2.5	2.8	67	0	0	0	0	0	.00	0	0
	S-23	0-30	3.3	2.8	42	8	.10	20	4	22	.13	35	6
	Mean	-	2.9	2.5	26	4	.04	12	1	8	.09	21	5
	StdDev.	-	0.4	0.9	18	3	.06	16	nd	6	.05	16	3
Mod. acid	S-13B	182	4.3	1.1	9	3	.10	18	5	16	.13	36	8
	S-18	0-45	5.9	0.4	3	(Normal growth)							
	S-20	45-87	4.8	2.1	39	5	.30	30	10	2	.41	36	10
	S-23	30-45	5.2	2.9	69	18	.19	35	2	10	.22	35	8
	Mean	-	5.0	1.6	30	7	.20	28	6	9	.25	36	9
	StdDev.	-	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Neutral	S-1B	66-122	7.2	2.3	21	10	.14	30	5	9	.15	32	5
	S-1D	15-30	7.1	2.6	35	16	.16	45	nd	18	.15	45	nd
	S-3A	40-135	7.3	2.0	18	11	.14	36	3	11	.16	38	5
	S-17	45-200	7.7	2.3	6	14	.11	32	6	13	.12	30	6
	S-23	45-107	7.6	2.4	32	13	.12	25	5	14	.11	36	5
	Mean	-	7.4	2.3	22	13	.13	34	5	13	.14	36	5
	StdDev.	-	0.2	0.2	10	2	.02	7	1	3	.02	5	1

Notes:
1. Acidity ranges: Very acid ph - 4.0; Moderately acid ph 4.1 - 6.5; Neutral ph 6.6 - 7.7
2. nd, not determined or insufficient data for meaningful statistics

Appendix C. Soil parameters and summary of soil constraints by depth, by site, Belt-Sand Coulee area, Montana, 1981.

SOIL PARAMETERS

	Textures					pH		SAR						EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion										
Soil Site Horizons	% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Ma	Na	SAR	Ratio Quality	Heavy Metal Contamination	Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
SITE 1A 0-6	40 4	33 2	26 4	Cl	F	6.9	G	8 48	1 .33	0 .93	.42	G	O	.90	G	10% COB	G	42 7	F	H	F	S	F	W	G	S	—	33	61	M F	25 40	80%	O	O	RANGE	ABUNDANCE OF CLAY BELOW 6"
6-12	22 4	45 6	32	C	P	7.1	G	4 .98	.87	.93	.54	G	O	.53	G	10% COB	G	38 2	F	VH	VF	S	P	—	—	—	—	—	—	CF	—	—	E	—	HILLSIDE	33' TO PARENT MATERIAL
12-27	18 4	45 6	36	C	P	7.2	G	4 .20	.87	.93	.58	G	O	.59	G	O	G	34 8	F	VH	VF	V S	P	—	—	—	—	—	—	CF	—	—	E	—		25 TO 40% SLOPES
27-33	14 4	50 0	35 6	C	P	7.3	G	3 81	1 .79	.93	.56	G	O	.60	G	O	G	30 7	F	VH	VF	VS	P	—	—	—	—	—	—	CF	—	—	E	—		HEAVY SOIL CONSISTENCIES
33													LARGE COBBLES																							
SITE 1D 0-6	62 4	10 0	27 4	Sl	F	3.5	P	10 81	4 99	1 51	.54	G		1.38	G	50% ANG. GR.	P	46 5	F	S	V fr	SS	G	W	G	S	—	48 COB	A	M F	< 5%	80%	O	O	HAY-FIELD	LOW PH AT LEVELS 0-6" AND 12-30"
6-12	52 4	16 0	31 6	Sl	F	7.1	G	34 83	20 52	1 86	.35	G	Ni Mo	2.60	G	40% ANG. FGR.	P	38 5	F	H	F	SS	F	—	—	—	—	—	—	M F	—	—	O	—	BOTTOM	EXHIBITED ABOVE MAXIMAL ACCEPTABLE LEVELS OF Ni
12-30	48 4	12 0	39 6	L	G	4.8	P	23 17	13 64	1 86	.43	G	O	1.95	G	10% GR.	G	42 0	F	H	fr	SS	G	—	—	—	—	—	—	C F	—	—	O	—		EXCESS FINE GRAVELS BETWEEN 0-12 INCHES
30-48	46 4	23 2	30 4	L	G	7.2	G	27 07	31 97	1 86	.34	G	O	2.75	G	10% GR.	G	40 3	F	H	fr	SS	G	—	—	—	—	—	—	C F	—	—	O	—		48" TO PARENT MATERIAL
SITE 14 0-6	26 8	37 6	35 6	Cl	F	7.3	G	5 37	2 25	93	.48	G	O	.70	G	5% FGR	G	36 0	F	SH	fr	SS	G	W	G	S	—	> 92	A	M F	< 5%	80%	O	O	BOTTOM RANGE	GOOD SOIL
6-12	68 0	11 6	20 4	Sl	F	7.6	G	4 59	1 55	93	.53	G	O	.53	G	O	G	31 2	F	SH	fr	S	G	—	—	—	—	—	—	M F			O	—		
12-18	65 2	18 0	16 8	Sl	F	7.7	G	5 75	2 25	93	.46	G	O	.60	G	O	G	32 3	F	H	fr	S	G	—	—	—	—	—	—	M F			S E	—		
18-42	59 2	18 0	22 8	Sl	F	7.8	G	4 20	2 25	93	.52	G	O	.58	G	O	G	30 6	F	H	fr	O	G	—	—	—	—	—	—	C F			S E	—		
42-66	56 8	19 6	23 6	Sl	F	7.9	F	4 20	1 79	93	.54	G	O	.52	G	O	G	31 0	F	H	V fr	O	G	—	—	—	—	—	—	—			S E	—		
66-92	53 2	23 6	23 2	SCl	F	7.9	F	4 59	2 25	93	.50	G	O	.63	G	O	G	25 2	F	H	V fr	SS	G	—	—	—	—	—	—	—			S E	—		
SITE 16 0-6	52 4	27 6	20 0	SCl	F	5.0	F	3 03	1 33	1 51	1 02	G	O	.45	G	10% GR	G	39 3	F	S	fr	SS	G	W	G	S	—	20	SS Col	M F	25 50%	80%	—	O	HILLSIDE RANGE	STEEP SLOPES 25 TO 50%
6-12	41 2	32 0	26 8	Cl	F	5.0	F	2 26	.87	.93	.74	G	O	.28	G	10% GR	G	33 3	F	H	F	SS	F	—	—	—	—	—		CF EC			—	—		20" TO PARENT MATERIAL
12-20	31 2	8 0	60 8	Sil	G	5.5	G	2 26	1 10	.93	.72	G	O	.31	G	20% GR	F	33 5	F	H	F	SS	F	—	—	—	—	—		CF EC			—	—		
								COBBLES AND ROCKS — MORE THAN 60%																												
SITE 18 0-6	63 2	18 4	18 4	Sl	F	5.5	F	3 03	2 25	.93	.57	G	O	.46	G	10% GR	G	33 6	F	S	fr	S	G	W	G	S	—	18	A	M F	5%	80%	—	O	BOTTOM RANGE	POOR TEXTURE (CLAYEY) BETWEEN 12 AND 18 INCHES
6-12	38 0	34 8	27 2	Cl	F	5.8	G	2 64	1 55	.93	.64	G	O	.35	G	20% GR	F	31 7	F	H	F	S	F	—	—	—	—	—		M F	—		—	—		18" TO PARENT MATERIAL
12-18	33 6	40 8	25 6	C	P	6.4	G	3 81	1 79	.93	.56	G	O	.52	G	20% GR	F	31 5	F	H	F	SS	F	—	—	—	—	—		C F	—		—	—		
								ANGULAR AND ROUNDED COBBLES																												

SOIL PARAMETERS

Soil Site Horizons		Textures: % Sand	% Clay	% Silt	Class	Texture Quality	pH: pH	pH Quality	SAR: Ca	Mg	Na	SAR	Ratio Quality	Heavy Metal Contamination	EC: Electrical Conductivity	EC Quality	Coarse Fragments: Coarse Fragments	Quality	Sat'n %: Sat'n %	Sat'n Quality	Consistancy: Dry	Moist	Wet	Consistancy Quality	Drainage: Drainage	Drainage Quality	Erosion: Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
SITE 21	0-6	50 0	21 2	28 8	l	G	6.7	G	9 38	3 46	4 67	1 84	G	O	1.58	G	20% FGR	F	49 6	F	SH	fr	S	G	W	G	S	—	30	A	MF CC	< 5%	80%	O	O	HAY- FIELD	EXCESS GRAVELS AT 12 TO 30 INCHES
	6-12	53 2	25 2	21 6	SCl	F	6.9	G	4 94	2 55	2 26	1 17	G	O	.86	G	30% FGR	F	42 8	F	SH	F	S	F	—	—		—			CF CC	—	—	O	—		PARENT MATERIAL AT 30"
	12-18	67 2	17 6	15 2	Sl	F	7.6	G	4 94	2 30	1 78	0 94	G	O	.87	G	40% FGR. 30% GR.	P	32 0	F	S	V fr	L	G	—	—		—			C C	—	—	O	—		
	18-30	64 4	20 0	15 6	Sl	F	7.3	G	9 93	4 36	2 48	0 93	G	O	1.34	G	40% FGR. 30% GR.	P	30 6	F	S	V fr	L	G	—	—		—			F C	—	—	O	—		
SITE 24	0-6	54 2	20 4	29 4	SCl	F	6.9	G	8 23	3 46	4 43	1 83	G	O	.90	G	50% GR.	G	46 3	F	SH	fr	SS	G	W	G	S	—	—	A	CF CC	< 8	60%	O	O	WHEAT- FIELD	GOOD SOIL
	6-12	36 8	28 0	35 2	Cl	F	7.3	G	11 03	2 30	2 02	.78	G	O	.88	G	O	G	44 9	F	H	F	S	F	—	—	—	—	—	—	CC	—	—	O	—		
	12-18	43 6	28 0	28 4	Cl	F	7.6	G	5 74	1 65	2 26	1 18	G	Mo	.55	G	O	G	44 2	F	SH	fr	S	G	—	—	—	—	—	—	CC	—	—	E	—		
	18-42	49 2	21 6	29 2	l	G	7.9	F	4 64	2 30	2 48	1 33	G	Mo	.60	G	10% GR.	G	40 7	F	SH	fr	S	G	—	—	—	—	—	—	O	—	—	E	—		
	42-72	21 2	37 6	41 2	Cl	F	8.1	F	2 99	3 70	2 48	1 36	G	Mo	.60	G	10% GR.	G	31 1	F	SH	fr	S	G	—	—	—	—	—	—	O	—	—	E	—		

SOIL PARAMETERS

Soil Site Horizons	Textures					pH		SAR					Heavy Metal Contamination	EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion		Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
	% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Mg	Na	SAR	Ratio Quality		Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality									
SITE 1B 0-6	26 4	2 0	71 6	Si.l	G	2.2	P	26 85	6 66	4 65	1 14	G	0	4.70	F	20% ANG. FGR.	F	37 7	F	SH	fr	VS	G	M W	G	S e	—	>48	A	0	5-15	0	0	0	MINE DUMP	2) 6) 8)
6-12	56 4	5 2	38 4	Sl	F	1.8	P	26 85	5 51	4 65	1 16	G	Mo	4.10	F	0	G	33 5	F	VH	V F	SS	P	—		—	—			0	—	—	0	0	AREA SLAG	2) 5)
12-20	50 4	6 0	43 6	Sl	F	3.5	P	22 95	7 77	4 65	1 19	G	Mo	4.00	F	0	G	32 5	F	VH	F	SS	F	—		—	—			0	—	—	0	0	PILE SOIL	2)
20-26	50 4	6 0	43 6	Sl	F	5.2	F	24 73	10 45	1 86	.44	G	Mo	2.40	G	0	G	32 3	F	VH	fr	OS	G	—		—	—			0	—	—	0	0	IMMED-IATELY	PAN LAYER AT 12-26'
26-48	32 4	26 0	41 6	Cl	F	7.2	G	20 85	13 64	1 86	.45	G	0	2.30	G	0	G	34 3	F	H	F	S	F	—		—	—			0	—	—	0	0	BELOW PILE	
SITE 1C 0-6	66 4	12 0	21 6	Sl	F	5.5	F	28 68	6 60	.93	.29	G	Mo	1.50	G	80% FG	P	26 3	F	L	L	L	P	W	G	S e	—	—	Coal	0	50	0	0	0	SLAG PILE	4) 5) 6) 8) 10)
0-6	58 4	22 0	19 6	SCl	F	2.5	P	3 03	1 10	.93	.65	G	Mo	.49	G	80% FG	P	30 9	F	L	L	L	P	—	—	—	—	—	—	0	—	0	0	0		2) 4) 5)
6-48	64 4	16 0	19 6	Sl	F	2.9	P	4 98	1 10	.93	.53	G	Mo	.65	G	80% FGR	P	33 1	F	L	L	L	P	—	—	—	—	—	—	0	—	0	0	0		2) 4) 5)
SITE 2A 0-6	32 4	30 0	37 6	Cl	F	2.5	P	6 92	4 99	.93	.41	G	Mo	1.30	G	30% FGR + GR	F	33 5	F	SH	fr	S	G	W	G	S e	—	34	A	0	15-25	0	0	0	BARREN AREA	2) 6) 7) 8) 10)
6-12	40 4	23 2	36 4	l	G	2.4	P	6 92	1 79	.93	.45	G	Fe Mo	1.05	G	30% FGR + GR	F	30 3	F	SH	fr	S	G	—	—	—	—	—	—	0	—	0	0	0	IN WHEAT-FIELD	2) 3)
12-18	34 4	31 6	34 0	C	P	2.1	P	5 37	1 79	1 32	.70	G	Fe Mo	1.12	G	0	G	32 3	F	H	F	S	F	—	—	—	—	—	—	0	—	0	0	0		1) 2) 3)
18-34	28 4	43 6	28 0	C	P	2.5	P	18 51	3 57	1 86	.56	G	Mo	2.12	G	0	G	36 5	F	H	F	S	F	—	—	—	—	—	—	0	—	0	0	0		1) 2)
SITE 2B 0-6	30 4	43 2	29 4	C	P	3.2	P	5 75	1 10	.93	.50	G	Mo	.72	G	30% FGR	F	38 3	F	SH	V fr	V SS	G	M W	G	S e	—	30	SS in place	0	15-25	0	0	0	RIDGE-TOP	1) 2) 6) 7) 8) 1
6-12	31 2	41 2	27 6	C	P	3.7	P	5 37	1 79	.93	.49	G	Mo	.68	G	20% FGR	F	43 3	F	H	F	SS	F	—	—	—	—		—	F C	—	0	0	—	RANGE	1) 2)
12-18	31 2	39 2	29 6	Cl	F	6.5	G	10 03	2 93	1 70	.67	G	Mo	1.15	G	30% FG	F	37 8	F	H	F	SS	F	—	—	—	—		—	F C	—	0	S E	—		
18-30	35 2	33 2	31 6	Cl	F	7.4	G	9 26	2 93	.93	.38	G	Mo	1.18	G	30% FG	F	31 7	F	H	F	SS	F	—	—	—	—		—	F C	—	0	S E	—		
													FRACTURED SANDSTONE																							
SITE 2C 0-4'	26 4	20 0	53 6	Si.l	G	1.8	P	6 85	9 53	1 86	.65	G	Fe B Mo	30.0	P	>50% FGR.	P	31 4	F	L	L	L	P	W	G	S e	—	—	Coal	0	>50%	0	0	0	SLAG PILE	2) 3) 4) 5) 6) 7) 8) 10) 11)

SOIL PARAMETERS

Soil Site Horizons	Textures					pH		SAR					Heavy Metal Contamination	EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion		Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
	% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Mg	Na	SAR	Ratio Quality		Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality									
SITE 3A 0-11	37 6	31 2	31 2	Cl	F	6.0	G	28 62	18 69	1 86	.38	G	Mo	2.90	G	50% GR	P	36 8	F	V H	L	L	P	W	G	S E	-	SS 53	S S	0	< 5%	0	0	0	BOTTOM OF	4) 5) 6) 7) 8)
11-16	42 0	33 2	24 8	Cl	F	7.0	G	27 84	20 52	1 86	.38	G	Mo	2.40	G	50% GR	P	29 1	F	V H	L	L	P	—	—	—	—	—		0	—	0	E	0	CINDER PILE;	4) 5) 6)
16-30	40 0	21 2	38 8	C	G	7.3	G	25 51	19 60	1 86	.39	G	Mo	2.40	G	Ce-mented	P	29 0	F	V H	L	L	P	—	—	—	—	—		0	—	0	E	0	PILES USED	4) 5) 6)
20-44	51 2	21 2	27 6	SCl	F	7.7	G	14 62	13 64	1 86	.49	G	Mo	1.60	G	0	G	27 3	F	S H	V fr	SS	G	—	—	—	—	—		0	—	0	M E	0	FOR FILL	PAN LAYER AT 16-30"
40-53	27 2	30 0	42 8	Cl	F	7.1	G	13 84	11 35	2 63	.74	G	Mo	1.80	G	20-30% GR.	F	33 9	F	H	F	S	F	—	—	—	—	—		0	—	0	V E	0		
													SAND STONE																							
SITE 3B 8'	41 2	31 2	31 2	Cl	F	3.0	P	11 28	45 57	4 65	.87	G	B Mo	27.0	P	30% GR.	P	40 1	F	L	L	L	P	W	G	S e	—	—	6021	0	> 30%	0	0	0	CINDER PILE	2) 3) 4) 11) 5) 6) 8) 10)
SITE 4A 0-6	71 2	10 0	18 8	Sl	F	1.9	P	24 9	18 10	4 65	1.0	G	Mo	4.20	F	60% FGR 1GR	P	44 9	F	SH	fr	OS	G	M W	G	S e	—	42	A	0	< 5%	0	0	0	RANGE	2) 4) 6) 7) 8)
6-12	82 0	8 0	10 0	Sl	F	2.7	P	20 85	15 02	1 86	.44	G	Mo	3.20	G	10% FGR 40% GR	P	34 3	F	SH	V fr	OS	G	—	—	—	—	—		0	—	0	0	—		2) 4)
12-18	57 2	20 0	22 8	SCl	F	2.6	P	15 17	12 38	4 65	1.25	G		4.00	F	50% FGR	P	29 5	F	SH	V fr	OS	G	—	—	—	—	—		0	—	0	0	—		2) 4)
18-42	38 0	8 0	54 0	Sil	G	2.4	P	17 12	12 38	4 65	1.21	G	Mo	3.90	G	0	G	37 4	F	H	fr	OS	G	—	—	—	—	—		0	—	0	0	—		2)
														ROCK																						
SITE 5A 0-6	64 0	11 2	24 8	Sl	F	3.4	P	13 84	4 03	1 86	.62	G	Mo	1.34	G	40% FGR	P	37 3	F	S	V fr	SS	G	W	G	S e	—	40	A	f c	< 3%	0	0	0	PARK AREA IN	2) 4) 6) 7) 8)
6-12	61 2	10 0	28 8	Sl	F	3.2	P	6 14	2 02	93	.46	G	Mo	.99	G	60% FGR	P	55 5	F	S	V fr	OS	G	—	—	—	—			0		—	0	—	SOUTH CENTRAL	2) 4)
12-18	63 6	8 0	28 4	Sl	F	3.4	P	7 62	2 67	1 86	.82	G	Mo	1.06	G	60% FGR	P	52 7	F	S	V fr	OS	G	—	—	—	—			0		—	0	—	SAND	2) 4)
18-40	54 0	23 2	28 8	SCl	F	3.2	P	33 28	6 86	1 86	.42	G	Mo	2.45	G	15% FGR	G	21 3	F	SH	fr	SS	G	—	—	—	—			0		—	0	—	COULEES	2)
												COBBLE SIZED STONES																								
SITE 6 0-6	65 6	11 2	23 2	Sl	F	3.2	P	6 14	2 25	93	.45	G	Mo	1.00	G	20% FGR 30% GR	P	24 6	P	SH	V fr	OS	G	W	G	S e	—	6	SS 61	0	S↓ 15	0	0	0	RANGE	2) 4) 13) 6) 7) 8)
													FRACTURED SANDSTONE ROCK																						HILL-SIDE	
SITE 7A 0-6	65 6	11 2	23 2	Sl	F	2.4	P	19 06	10 64	4 65	.60	G	Mo	8.00	F	10% FGR	G	38 9	F	SH	fr	S	G	W	G	S e	—	6	SS 61	E C	25	0	0	0	RANGE	2) 6) 7) 8) 10)
													SANDSTONE																						HILL-SIDE	

SOIL PARAMETERS

		Textures					pH		SAR						EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion										
	Soil Site Horizons	% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Mg	Na	SAR	Ratio Quality	Heavy Metal Contamination	Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
SITE 8	6'	34.0	11.2	54.8	Sil	G	1.9	P	.80	9.46	7.72	3.41	G	NiFe MnMo	20.0	P	>50% GR	P	44.8	F	L	L	L	P	W	G	S e	—	—	Coal	0	>50	0	0	0	CINDER PILE FILL MATERIAL	2) 3) 11) 4) 5) 6) 8) 10)
SITE 9	0-6	17.6	50.0	32.4	C	P	3.5	P	17.73	14.10	1.86	.47	G	Mo	3.00	G	0	G	46.3	F	H	F	S	F	P	P	S e	—	39	SS Col	0	25	0	0	0	RANGE HILLSIDE	1) 2) 12) 6) 7) 8) 10)
	6-12	13.6	26.0	60.4	Sil	G	3.4	P	30.18	10.89	1.86	.41	G	Mo	2.90	G	0	G	48.2	F	H	F	S	F	—	—	—	—	—	—	0	—	—	0	—		2)
	12-18	10.4	15.2	74.4	Sil	G	3.4	P	21.62	6.78	1.86	.49	G	Mo	2.30	G	0	G	56.6	F	H	F	S	F	—	—	—	—	—	—	0	—	—	0	—		2)
	18-39	41.6	5.2	53.2	Sil	G	4.5	F	23.17	22.34	1.86	.39	G	Mo	2.60	G	0	G	39.9	F	H	F	S	F	—	—	—	—	—	—	0	—	—	0	—		2)
SANDSTONE																																					
SITE 10	0-6	34.0	7.2	58.8	Sil	G	3.1	P	18.51	19.60	1.86	.43	G	Mo	3.60	G	30% FGR	F	32.8	F	SH	fr	SS	G	Mod Well	G	S e	—	27	A	0	3	0	0	0	ROAD-SIDE	2) 6) 7) 8)
	6-12	51.2	6.0	42.8	Sl	F	3.0	P	19.06	31.84	4.65	.92	G	Mo	4.60	F	30% FGR	F	28.1	F	H	fr	SS	G	—		—	—	—	—	0	—	—	0	—	DRAIN-AGE	2)
	12-18	47.6	4.0	48.4	Sl	F	2.8	P	17.12	27.23	4.65	.99	G	Mo	5.00	F	30% FGR	F	27.5	F	S	Vfr	SS	G	—		—	—	—	—	0	—	—	0	—	COLLECTS ALLUVIUM	2)
	18-27	55.6	4.0	49.4	Sl	F	2.7	P	19.06	36.40	4.65	.88	G	Mo	6.00	F	30% FGR	F	29.2	F	S	Vfr	SS	G	—		—	—	—	—	0	—	—	0	—	FROM CIN-DER PILES	2)
COBBLES																																					
SITE 11	0-6	14.4	7.2	78.4	Sil	G	2.3	P	30.71	38.71	4.65	.79	G	Mo	7.00	F	0	G	41.7	F	SH	fr	S	G	P	P	S e	—	65	SS	0	25	0	0	0	RANGE HILLSIDE	2) 12) 6) 8) 10)
	6-12	17.2	11.6	71.2	Sil	G	2.2	P	21.01	19.25	4.65	1.04	G	Mo	7.00	F	0	G	40.9	F	SH	fr	S	G	—	—	—	—	—	—	0	—	—	0	—		2)
	12-18	21.6	7.2	71.2	Sil	G	2.2	P	21.01	15.79	4.65	1.08	G	Mo	6.60	F	0	G	40.1	F	SH	fr	S	G	—	—	—	—	—	—	0	—	—	0	—		2)
	18-48	16.8	21.2	62.0	Sil	G	2.5	P	17.12	14.64	4.65	1.17	G	Mo	5.00	F	0	G	41.6	F	H	F	S	F	—	—	—	—	—	—	0	—	—	0	—		2)
	48-65	24.4	5.2	70.4	Sil	G	2.7	P	13.06	10.45	1.86	.54	G	Mo	3.30	G	0	G	38.0	F	VH	VF	S	P	—	—	—	—	—	—	0	—	—	0	—		2) 5)
SANDSTONE																																					
SITE 12	0-6	35.2	2.0	62.8	Sil	G	2.2	P	11.28	19.25	4.65	1.19	G	Fe Mo	5.20	F	10% GR	G	46.5	F	S	fr	SS	G	P	P	S e	—	—	SS Col	f F	40	0	0	26	RANGE	2) 3) 12) 6) 8) 9) 10)
	6-12	34.8	5.2	60.0	Sil	G	2.3	P	13.22	23.82	4.65	1.08	G	Mo	5.20	F	40% COB	P	32.9	F	S	fr	S	G	—	—		—	—		0	—	—	0	—	HILL-SIDE	2) 4)
	12-26	58.8	3.2	46.0	Sl	F	2.1	P	13.22	24.97	4.65	1.06	G	Mo	6.40	F	10% COB	G	33.0	F	S	fr	SS	G	—	—		—	—		0	—	—	0	—		2)
WATERTABLE																																					

SOIL PARAMETERS

Soil Site	Horizons	Textures: % Sand	% Clay	% Silt	Class	Texture Quality	pH: pH	pH Quality	SAR: Ca	Mg	Na	SAR	Ratio Quality	Heavy Metal Contamination	EC: Electrical Conductivity	EC Quality	Coarse Fragments: Coarse Fragments	Quality	Sat'n %: Sat'n %	Sat'n Quality	Consistancy: Dry	Moist	Wet	Consistancy Quality	Drainage: Drainage	Drainage Quality	Erosion: Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
SITE 13	0-6	36 8	25 2	38 0	Cl	F	3.7	P	16 18	10 45	1 86	.51	G	0	1.90	G	60% FGR	P	34 5	F	L	L	OS	P	MW	G	S e	—	44	A Col	0	8	0	0	36	RANGE	2) 4) 5) 6) 7) 8) 9)
	6-12	32 8	29 2	38 0	Cl	F	3.3	P	6 14	4 53	.93	.40	G	0	1.34	G	50% FGR	P	38 2	F	S	V fr	OS	G	—	—	—	—	—	—	0	—	—	0	—		2) 4)
	12-18	58 8	10 8	30 4	Sl	F	2.6	P	10 74	11 35	1 86	.56	G	Fe Mo	2.80	G	10% GR	G	31 5	F	S	V fr	OS	G	—	—	—	—	—	—	0	—	—	0	—		2) 3)
	18-44	51 2	21 2	27 6	SCl	F	2.5	P	17 12	20 36	4 65	1 07	G	Mo	4.00	F	20% GR	F	32 8	F	SH	fr	SS	G	—	—	—	—	—	—	0	—	—	0	—		2)
												FRACTURED SANDSTONE																									
SITE 13B	6'	44 2	17 4	38 4	l	G	4.3	P	8 87	4 53	.93	.36	G	Fe	1.07	G	10% GR	G	70 4	F	L	L	OS	P	W	G	S e	—	—	Coal	0	45	0	0	0	SLAG PILE	2) 3) 5) 6) 8) 10)
SITE 15	0-6	70 0	17 2	12 8	Sl	F	2.6	P	3 03	1 79	.93	.60	G	Mo	.56	G	50% FGR	P	37 1	F	S	V fr	OS	G	MW	G	S e	—	—	A Col	0	<5	0	0	0	RANGE	2) 4) 6) 8)
	6-10	64 0	13 2	22 8	Sl	F	2.5	P	3 42	1 79	.93	.58	G	0	.62	G	50% FGR	P	45 4	F	S	V fr	OS	G	—	—	—	—	—	—	0	—	—	0	—		2) 4)
	10-18	80 0	13 2	6 8	Sl	F	2.6	P	3 03	1 10	.93	.65	G	Fe Cu	.55	G	40% FGR	P	33 7	F	SH	F	SS	F	—	—	—	—	—	—	0	—	—	0	—		2) 3) 4)
	18-42	36 0	27 2	36 8	Cl	F	3.3	P	4 97	1 33	1 32	.74	G	Mo	.70	G	0	G	31 6	F	SH	F	S	F	—	—	—	—	—	—	0	—	—	0	—		2)
	42-80	32 0	23 2	44 8	l	G	7.0	G	4 97	1 79	2 48	1 35	G	Mo	.79	G	0	G	35 5	F	SH	F	SS	F	—	—	—	—	—	—	0	—	—	0	—		
SITE 17	0-6	53 2	20 8	26 0	SCl	F	2.3	P	19 06	69 60	8 52	1 28	G	Mn Mo	6.20	F	0	G	58 5	F	SH	fr	S	G	MW	G	S e	—	—	A	0	<5	0	0	0	RANGE	2) 3) 6) 8)
	6-12	44 0	24 4	31 6	L	G	2.9	P	18 59	36 08	4 61	.88	G	Mo	.39	G	0	G	32 3	F	H	F	SS	F	—	—		—	—		0	—	—	0	—		2)
	12-18	48 0	24 4	27 6	L	G	3.3	P	22 95	45 57	6 59	1 13	G	Mo	4.00	F	0	G	31 0	F	SH	F	SS	F	—	—		—	—		0	—	—	0	—		2)
	18-44	52 0	24 4	23 6	SCl	F	7.8	G	6 07	31 97	7 67	1 76	G	Mo	2.70	G	0	G	33 7	F	SH	F	S	F	—	—		—	—		0	—	—	0	—		
	44-78	51 6	20 4	28 0	SCl	F	7.7	G	6 07	26 96	3 02	.74	G	Mo	1.94	G	0	G	27 3	F	SH	F	S	F	—	—		—	—		0	—	—	0	—		
SITE 19	0-6	78	10 4	11 6	Sl	F	3.9	P	6 04	6 04	3 47	1 70	G	0	1.04	G	30% FGR	F	43 1	F	S	V fr	OS	G	W	G	S	—	60	A	0	3	0	0	0	CULTIVATED FIELD	2) 8)
	6-12	58 8	18 4	22 8	Sl	F	3.8	P	5 44	2 30	2 99	1 52	G	0	.96	G	50% FGR 10% GR	P	40 6	F	S	fr	OS	G	—	—	—	—			0	—	—	0	—	MIXED COAL	2) 4)
	12-18	80 8	10 4	8 8	LS	P	4.2	P	5 44	2 06	4 67	2 41	G	0	.94	G	50% FGR	P	46 1	F	SH	fr	OS	G	—	—	—	—			0	—	—	0	—	SLAG & SOIL	1) 2) 4)
	18-42	53 6	26 4	20 0	SCl	F	7.2	G	8 53	3 21	3 71	1 53	G	Mo	1.00	G	10% GR	G	43 8	F	H	F	S	F	—	—	—	—			0	—	—	0	—		
	42-60	50 8	22 4	26 8	SCl	F	7.1	G	7 14	2 96	2 27	1 01	G	0	.90	G	10% GR	G	38 8	F	H	F	S	F	—	—	—	—			0	—	—	0	—		
												COBBLES																									

SOIL PARAMETERS

		Textures					pH		SAR						EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion									
	Soil Site Horizons	% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Ma	Na	SAR	Ratio Quality	Heavy Metal Contamination	Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
SITE 20	0-6	65 0	14 4	20 6	SL	F	4.5	F	4 39	1 89	1 54	87	G	0	.59	G	20% F. GR 30% GR	P	34 6	F	S	V fr	OS	G	M W	G	S	–	34	A	0	C S	0	0	0	RANGE	2) 4) 7) 8)
	6-12	82 0	11 2	6 8	LS	P	3.0	P	3 84	1 40	1 30	.80	G	Mo	.62	G	20% FGR 30% GR	P	37 7	F	S	V fr	OS	G	—	—	—	—	—	—	0	—	—	0	—		1). 2) 4)
	12-18	55 2	3 6	41 2	SL	F	2.5	P	67 61	2 80	1 54	.26	G	Mo	2.85	G	30% FGR	F	39 1	F	SH	fr	SS	G	—	—	—	—	—	—	0	—	—	0	—		2)
	18-34	59 2	11 6	29 2	SL	F	4.9	F	39 30	6 99	1 07	.22	G	0	2.10	G	10% GR	G	39 4	F	H	V F	S	P	—	—	—	—	—	—	0	—	—	0	—		2) 5)
													SANDSTONE																								
SITE 22	0-12	48 0	7 0	45 0	L	G	3.6	P	1 12	2 47	6 52	4 87	G	0	9.60	G	80% GR	P	37 8	F	L	L	OS	P	W	G	S e	–	12	A	0	3	0	0	0	CINDER PILE	2) 4) 5) 6) 7) 8)
											ALLUVIAL COBBLES																									USED FOR FILL	
																																				2,4,5,7, 6,8	
SITE 23	0-6	63 2	20 8	16 0	SCl	F	2.9	P	11 58	13 33	1 78	.50	G	Fe Mo	2.80	G	10% FGR	G	43 8	F	H	F	S	F	W	G	Mod	–	42	A	0	C 10	0	0	0	ALLUVIAL SLAG	
	6-12	43 2	27 2	29 6	Cl	F	3.8	P	74 35	12 83	1 30	.20	G	Fe	2.80	G	0	G	39 7	F	H	F	S	F	—	—	—	—	—	—	0	—	—	0	—		2) 3) 5) 7) 8)
	12-18	45 6	5 6	48 8	Sl	F	5.2	F	68 86	16 95	1 78	.27	G	Mo	2.90	G	0	G	35 1	F	V H	V F	SS	P	—	—	—	—	—	—	0	—	—	0	—		2) 3)
PAN LAYER	18-42	39 6	28 8	31 6	Cl	F	7.6	G	31 69	16 95	2 02	.41	G	0	2.40	G	50% FGR	F	35 9	F	H	F	OS	F	—	—	—	—	—	—	0	—	—	E	—		
18-24 INCHES												ROUND COBBLES																									

SOIL PARAMETERS

	Soil Site Horizons	Textures					pH		SAR						EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion										
		% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Ma	Na	SAR	Ratio Quality	Heavy Metal Contamination	Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
BITTON	0-4				1	G	7.6	G							? <2	G	15% GR	F			S	V fr	OS	G	W	G	M	—	} 50	Sh SS	M F	10-65%	60-80	S E	O	RANGE	LOAMY TO CLAYEY
	4-11				1	G	7.8	G							? <2	G	20% GR	F			SH	fr	SS	G	—	—	—	—	—	—	M F	—	—	S E	—		SUBSOILS WITH MORE
	11-21				1	G	8.0	F							? <2	G	25% GR	F			SH	fr	SS	G	—	—	—	—	—	—	C F	—	—	E	—		THAN 35% BY
	21-46				1	G	8.0	F							? <2	G	65% G	P			S	fr	S	G	—	—	—	—	—	—	C F	—	—	E	—		VOLUME OF GRAVELS,
	46-64				1 SI	G↓ F	8.0	F							? <2	G	19% GR	F			SH	fr	OS	G	—	—	—	—	—	—	F F	—	—	E	—		COBBLES OR STONES
ROY	0-6				1	G	6.8	G							? <2	G	15% St+ GR	F			SH	V fr	—	G	W	G	M	—	—	SS Ig	M F	10↓ 65%	60↓ 80%	O	O	RANGE	SAME AS BITTON
	6-14				Cl	F	7.0	G							? <2	G	45% St	P			H	fr	S	G	—	—	—	—	—	—	M F	—	—	O	—	OCC. CROPS	
	14-32				Cl	F	7.0	G							? <2	G	50% St+ GR	P			H	F	S	F	—	—	—	—	—	—	M F	—	—	O	—		
	32-60				SCl	F	7.8	F							? <2	G	50% St+ GR	P			H	fr	S	G	—	—	—	—	—	—	O	—	—	S E	—		
TALLY	0-8				FSl	G	7.0	G							<2	G	O	G			S	V fr	OS	G	W	G	S	—	—	A		15↓ 35%	60↓ 80%	O	O	AGRI-CULTURE	LOAMY SUBSOILS
	8-15				FSl	G	7.6	G							<2	G	O	G			S	V fr	OS	G	—	—	—	—	—	—	C F	—	—	O	—	IRR. & NON IRR.	
	15-30				FSl	G	7.8	F							<2	G	O	G			S	V fr	OS	G	—	—	—	—	—	—	C F	—	—	E	—	RANGE	
	30-60				lFS	F	7.8	F							<2	G	O	G			S	V fr	OS	G	—	—	—	—	—	—	F	—	—	E	—		
STRAW (FROM STRAW RIVRA COMPLEX)																																					LOAMY SUBSOILS UNDERLAIN BY LOOSE SANDS OR SANDS & GRAVEL BETWEEN 20 AND 40 INCHES
TWIN CREEK (SiCl)																																					LOAMY SUBSOILS WITH CLAYEY OR CLAY SURFACES

SOIL PARAMETERS

		Textures					pH		SAR						EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion										
	Soil Site Horizons	% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Mg	Na	SAR	Ratio Quality	Heavy Metal Contamination	Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
FARNUFF	0-7				l	G	7.4	G							O	G	O	G			H	vfr	SS	G	W	G	S			A	MF	4↓ 8	80%	O	O	AGRICULTURE	
LOAM	7-15				cl	F	7.6	G							<2	G	O	G			VH	fr	S	G	—	—	—			—	MF	—	—	O	—	IRR. & NON IRR.	LOAMY SUBSOILS
	15-24				l	G	8.3	F							<2	G	O	G			H	fr	S	G	—	—	—			—	MF	—	—	E	—	RANGE	
	24-36				l	G	8.4	F							<2	G	10% GR	G			H	fr	S	G	—	—	—			—	CF	—	—	E	—		
	36-60				l SiCl	G↓ F	8.5	P							<2	G	O	G			H	vfr	S	G	—	—	—			—	FF	—	—	E	—		
STRAW	0-10				l	G	7.6	G							? <2	G	O	G			SH	vfr	SS	G	W	G	S			A	MF	< 8%	80%	SE	O	AGRICULTURE	LOAMY SUBSOILS
LOAM	10-27				l	G	8.0	F							? <2	G	O	G			SH	vfr	SS	G	—	—	—			—	CF	—	—	E	—	IRR & NON IRR.	
	27-38				l	G	8.0	F							? <2	G	O	G			H	vfr	SS	G	—	—	—			—	CF	—	—	E	—	RANGE	
	38-54				Sil	G	8.3	F							? <2	G	O	G			H	vfr	SS	G	—	—	—			—	FF	—	—	E	—		
	54-66				ls	F	7.6	G							? <2	G	O	G			S	vfr	OS	G	—	—	—			—	O	—	—	E	—		
TWIN CREEK	0-7				l	G	7.0	G							O	G	O	G			H	vfr	SS	G	W	G	S			A	CF	< 8%	80%	O	O	AGRICULTURE	LOAMY SUBSOILS
LOAM	7-13				l	G	7.0	G							<2	G	O	G			H	fr	SS	G	—	—	—			—	CF	—	—	O	—	IRR. & NON IRR.	
	13-19				l	G	7.6	G							<2	G	O	G			H	fr	SS	G	—	—	—			—	CF	—	—	SE	—	RANGE	
	19-25				l	G	7.6	G							<2	G	O	G			—	—	—	—	—	—	—			—	FF	—	—	E	—		
	25-45				l	G	7.9	F							<2	G	O	G			H	fr	SS	G	—	—	—			—	FF	—	—	E	—		
	45-60				cl	F	8.0	F							<2	G	O	G			H	fr	S	G	—	—	—			—	O	—	—	E	—		
FERGUS	0-4				cl	F	7.2	G							? <2	G	O	G			SH	fr	S	G	W	G	S			A	MF	2%	80%	O	O	AGRICULTURE	CLAYEY SUBSOILS
SiCl	4-9				SiCl	F	7.2	G							? <2	G	O	G			H	fr	S	G	—	—	—			—	MF	—	—	O	—	NON-IRR.	
	9-28				cl	F	7.6	G							? <2	G	O	G			H	fr	S	G	—	—	—			—	MF	—	—	O	—	OCCA-	
	28-34				cl	F	8.0	F							? <2	G	O	G			H	fr	S	G	—	—	—			—	F	—	—	SE	—	SIONAL	
	34-40				SiCl	F	8.4	F							? <2	G	O	G			H	fr	S	G	—	—	—			—	F	—	—	E	—	IRR &	
	40-47 REGOLITH				cl	F	8.6	P							?	?	O	G			H	fr	S	G	—	—	—			—	O	—	—	E	—	RANGE	

SOIL PARAMETERS

Soil Site	Horizons	Textures					pH		SAR						EC		Coarse Fragments		Sat'n %		Consistancy				Drainage		Erosion										
		% Sand	% Clay	% Silt	Class	Texture Quality	pH	pH Quality	Ca	Ma	Na	SAR	Ratia Quality	Heavy Metal Contamination	Electrical Conductivity	EC Quality	Coarse Fragments	Quality	Sat'n %	Sat'n Quality	Dry	Moist	Wet	Consistancy Quality	Drainage	Drainage Quality	Erosion	Erosion Quality	Soil Depth, in.	Parent Material	Roots	Slope %	Vegetation	CaCO	Water Table, in.	Land Use	Summary of Soil Constraints
RIVRA	0-8				GR SI	P	7.4	G							<2	G	20% GR	F			S	V fr	OS	G	W	G	S	—	—	A	C F	≤ 5	80%	S E	> 40	PASTURE & RANGE	VERY GRAVELLY OR
GRAVELLY	8-32				VGR LS	P	8.0	F							<2	G	60% GR 10% C	P			L	L	L	P	—	—	—	—	—	—	C F	—	—	E	—	SUBJECT TO	VERY COBBLY SAND OR
SI (10)	32-60				VGR S	P	8.0	F							<2	G	55% GR 15% COB	P			L	L	L	P	—	—	—	—	—	—	F F	—	—	E	—	FLOODING	LOAMY SAND SUBSOILS
(210)																																					AT DEPTHS OF LESS
																																					THAN 12 INCHES
BIG TIMBER	0-3				Cl	F	8.0	F							—	—	0	G			SH	fr	S	G	W	G	S	—	18	SS Sh	—	15↓ 40	80%	E	0	RANGE	CLAYEY SUBSOILS
	3-6				Cl	F	8.0	F							—	—	.	G			SH	fr	S	G	—	—	—	—	—	—	—	—	—	E	—		UNDERLAIN BY SHALES
	6-18				C	P	8.0	F							—	—	20%	F				fr		G	—	—	—	—	—	—	—	—	—	E	—		OR SILTSTONES BE-
	18-60				SC	P	8.0	F							—	—	> 50%	P				—		—	—	—	—	—	—	—	—	—	—	E	—		TWEEN 10 AND 20
									SANDSTONE SILTSTONE SHALE																												INCHES
CASTNER	0-2				Sl	F	7.2	G							0	G	GR 25%	F			S	V fr	SS	G	W	G	S	—	16	SS	M F	15↓ 40	80%	O	O	RANGE	LOAMY TO CLAYEY SUB-
	2-10				l	G	7.6	G							<2	G	COB & GR 50%	P			SH	V fr	SS	G	—	—	—	—	—	—	M F	—	—	S E	—		SOILS W/ MORE THAN
	10-16				l	G	8.4	F							<2	G	COB & GR 75%	P			SH	V fr	SS	G	—	—	—	—	—	—	M F	—	—	E	—		35% BY VOLUME OF
														SANDSTONE																							GRAVELS, COBBLES OR
																																					STONES UNDERLAIN BY
																																					HARD ROCK BETWEEN
																																					10 AND 20 INCHES
DARRET	0-4				Si Cl	F	7.0	G							0	G	0	G			SH	fr	S	G							M F			O			CLAYEY SUBSOILS
	4-8				Si Cl	F	7.0	G							0	G	0	G			H	fr	S	G							M F			O			UNDERLAIN BY SHALES
	8-13				Si C	P	7.4	G							0	G	0	G			H	fr	V S	G							M F			O			OR SILTSTONES BE-
	13-19				Cl	F	8.0	F							0	G	20% GR	F			H	F	S	F							M F			S E			TWEEN 20 AND 40
	19-28				Cl	F	8.0	F							0	G	20% GR	F			SH	fr	S	G							F F			M E			INCHES
	28-36	SOFT REGOLITH				P	—	—							0	G															F F			M E			

Appendix D. Vegetation transect data sheets, Belt-Sand Coulee area, Montana, 1980.

TRANSECT A

AGSP-RHTR

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location

Sec T R

Type Agsp-Rhtr	Slope (%) 59%
Stand No. or cluster BECT 7-5	Aspect N31W
Location	Soil clay-rocky
Date 9	Elevation 3700
Worker(s) DB LL	Topography 3
Page ___ of ___	Configuration 1
Photo # 3,4	Range condition
	Range trend

N62E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	13	14	35	46	5?	18	3?	28	32	41	28	9	10	5?	14	40	52	73	50	24	33.8/100
Rock	9	6		35	50		9	49	47	20	14	5	15	16	9	10	11	15	11	2	21/100
Litter	45	77	11	17	8	67	40	12	10	36	9?	7	17	21	7?	40	[illegible]	10	7	7?	38?/100
Lichens	T	[illegible]	9	8	7	5	2	8	10	2	4	[illegible]	1	2	3	4	3	2	2	T	3.83/100
Moss	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	12	3	1	1	6	8	[illegible]	3	1	6	T	0	L	1	2.63/75
Agsp	1?	4	1	12	7	29	4	7	8	15	11	17	9	12	11	8	13	5	8	7	13.45/100
[illegible]	-	11	..	-	-	-		-	0	1	-	1	-	-	-	-	-	-	-		.95/20
Agcm			11	.	T	1	3	1	1	-	-	-	1	-	-	-	1	-	-		.78/45
Brjp			T	1	-	-	1	-	-	T	-	-	2	T	-	-	-	-	-		.28/30
Bo..					3	7	24	16	T	-	T	-	34	1	-	7	5	-	-		4.33/50
?p pr sp. Complex						7	-	6	22	-	-	-	-	-	-	T	2	2	-	43	4.13/35
Arfe															5	8	-	-	T		.69/15
Lomac					2	-	-	-	-	-	-	1	2	-	-	-	-	-	-	T	.28/20
Lede	-	5	-	1	1	1	4	T	T	-	1	1	1	-	1	-	1	T	1		.98/70
Chvi		3?	3	-	1	4	-	-	-	-	3	-	-	-	-	-	-	-	5		.9/30
[illegible]				T	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-		.05/10
Erigeron sp.					1	-	-	-	-	-	-	-	-	T	-	-	-	-	-		.08/10
Popu "										3	T	-	-	-	-	-	-	-	-		.18/10
Comandra umb											T	-	-	1	-	-	-	-	-		.05/10
A.Sr			2	-	-	-	-	-	6	T	-	2	-	T	-	-	-	-			.55/25
Oppo							2	-	-	-	-	-	-	-	-	-	-	-			.1/5
Syal														8	-	2	-	-			.5/10
Chvi						3	-	-	-	-	-	-	3	-	-	-	-	-			.3/10
[illegible]	[illegible]	T	-	-	-	-	-	-	-	-	51	-	-	-	-	-	-	-		7	7.45/25
?in AL							23	2	-	-	-	-	-	-	-	-	-	-			1.25/10

Br ja, Arlo, Trdu, Clun, crdo, Lipu, Prvi

?

Topography:	Configuration:	Coverage Class	Range	Midpoint
1. ridge	1. convex	1	0- 5%	2.5%
2. upper slope	2. straight	2	5- 25%	15.0%
3. mid slope	3. concave	3	25- 50%	37.5%
4. lower slope	4. undulating	4	50- 75%	62.5%
5. bench or flat		5	75- 95%	85.0%
6. streambottom		6	95-100%	97.5%

TRANSECT B

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location

Type Agsp-Rhtr
Stand No. or cluster ~~BLT~~ 7-3,4
Location
Date 9-9
Worker(s) DB LL
Page ____ of ____
Photo # 22, 23

Slope (%) 42
Aspect S 18 E W
Soil
Elevation 3740
Topography 2
Configuration 1
Range condition 1
Range trend

Lincruns N86E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	16	–	19	3	–	8	15	28	10	6	7	14	5	31	–	5	–	–	10	–	6.85/70
Rock	35	–	21	8	6	68	11	7	55	14	12	7	10	15	10	12	–	–	7	–	14.9/80
Litter	46	100	57?	89	74	17	74	63?	35	79	80	76	84	54?	90?	82?	100	100?	83	100	75.25/100
Lichens	3	–	T	–	–	7	–	2	–	T	1	3	7	–	–	1	–	–	–	–	0.9/45
Moss	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0/10
Agsm	2	–	3	3	–	1	–	3	1	5	4	3	2	1	3	2	2	3	–		1.9/60
Agsp	5	12	5	1	6	23	9		8	11	2	1	6	28	4	4	T	9	8	T	7.15/95
Brja	2	1	2	T	–	–	–		–	–	2	–	–	–	–	2	T	3	1	–	0.7/45
Brte			1	–	4	–	–		–	–	–	–	–	–	–	–	–	–	1	–	0.3/15
Stvi				4	–	2	5	11	12	5	–	–	7	–	–	–	–	–	11	6	3.3/45
Bogr						10	–		–	–	–	8	–	2	–	5	–	–	–	–	1.25/20
Lede		1	2	–	1	–	–	–		–	5	–		–	–	1	–	1	1	–	0.6/35
Trifolium spp	1	–	–	–	–	–			–	–	–	–		–	–	–	–	–	–	–	0.05/5
Vicia? ~~Astragalus~~ "			1	–	4	7	2	3	1	–	3	1	–	–	–	5	–	–	–	–	1.35/45
trdu					1	–			–	–	–	–		–	–	–	–	2	–	–	0.25/15
Lotus? ~~spp.~~ (clumping)					T	–			–	T	–	–		–	–	–	–	–	–	–	0.05/10
																		1	?	–	0.08/10
Popo		4	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	0.3/10
Ccdo				3	45	–	–	–	–	–	–	–	–	–	–	–	–	–	–		2.4/10
RhTr	T	41	T	14	–	–	?	T	–	5	2	2	12	–	27	–	18?	10	9	?	13.98/60

Arlo

Pste

Arfr

Lyja

Lipa

Topography:	Configuration:
1. ridge	1. convex
2. upper slope	2. straight
3. mid slope	3. concave
4. lower slope	4. undulating
5. bench or flat	
6. streambottom	

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT C

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location

Type Popr-Anal
Stand No. or cluster BELT 7-6
Location
Date 9-9
Worker(s) [illegible]
Page ____ of ____
Photo # 18,19

Slope (%) 44
Aspect N 7° E
Soil
Elevation 3760
Topography 3
Configuration 4
Range condition
Range trend

S82°E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground																					33.65/100
Rock																					1.65/80
Litter	68													63							53.15/85
Lichens																					0.13/10
Moss																					7.98/85
[illegible]															T						0.38/15
[illegible]																					25.05/100
[illegible]																					0.23/20
Ca... [illegible]																					1.75/15
																					0.8/15
[illegible]																					
? Aster falc																					0.25/10
Erdu																					0.25/5
Lear																					0.05/5
[illegible]																					0.13/10
[illegible]																					1.7/65
[illegible]																					0.73/30
[illegible]																					0.9/25
[illegible]																					1.75/50
Fragaria vesca																					0.05/5
Taof																					1.45/30
[illegible]																					0.15/10
[illegible]																					0.15/10
? [illegible]																					0.35/20
? [illegible]																					0.25/10
? [illegible]																					0.3/5
? [illegible]																					0.95/5
? [illegible]																					0.4/5
[illegible]																					0.7/20
																					0.25/10
? [illegible]																					1.05/30
[illegible]																					1.15/35
[illegible]																					0.03/5
[illegible]																					0.48/25
																					0.25/10
																					2.4/40
																					3.1/60
																					4.08/60

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT D　　　　　　　　　　　　　　　　　　　　PoPR - 540C

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location
Sec T R

Type Popr-Syoc
Stand No. or cluster 7-19
Location ______
Date 9/8
Worker(s) LL + DB
Page 1 of ______
Photo # 7-8

Slope (%) 19%
Aspect N338W
Soil ______
Elevation 3580
Topography 4
Configuration 4
Range condition ______
Range trend ______

Line bearing S57°W

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	4	2	-	1	-	-	-	-	-	1	-	3	-	-	-			-	-	-	.55/25
Rock	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	
Litter	96	95	100	99	100	100	100	100	100	99	100	97	[illegible]		100	100	100	100	100	100	99.45/100
Lichens	-	-	-	-	-	-	-	-	-	-	-	-	-			-		-	-	-	
Moss	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	
Popr	8.5	78	75	71	47	-	-	-	-	-	-	-	-	-	-	6	53	22	28	[illegible] T	27.25/50
Agsm	5	8	10	6	-	-	-	-	-	-	-	-									1.45/20
BrIn	-	-	-	-	3	-	-	-	42	73	11	8	3	T	14	1	4	5	-	-	8.38/55
Acmil				7	2	-	-	-	-				-	-	-	-	3	3	-	-	.75/20
Trifolium spp	T	-	-	-	-	-	-	-	-				-	-	-	-	-	-	-	-	.03/5
Chm	T	-	-		-	-	-	-					-	-	-		-	-	-	-	.03/5
Gaco		1	-	-	-	-	-	-	-		-		-	-	-	-	-	-	-	-	.05/5
Ciar							T	3	-				-	-	-		[illegible]	-	-	-	.575/15
Monarda spp								6	-	-	-		-	-	-	-	-	-	-	-	.3/5
Somi																		10	-	-	.5/5
Artab	-	-						13	-	-	-	-				1	-	1	-	5	.9/10
Arfr	1	-	-		-	-	-	-		-	-	-				-	-	-	-	-	.05/5
Syoc	2	37	28	36	71	54	86	35	[illegible]	[illegible]	2	10	37	[illegible]	[illegible]	9	7	2	15	13	31.55/100
Coun	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.25/5
Boar						T	-	-	-	-	2	-	19	13	5	17	10	5	51	2	5.73/50
Crdo													6	[illegible]	22	7	4	5	6	-	59.85/35
Anal														[illegible]	-	-	-	-	-	-	1.15/5

Topography:	Configuration:	Coverage Class	Range	Midpoint
1. ridge	1. convex	1	0- 5%	2.5%
2. upper slope	2. straight	2	5- 25%	15.0%
3. mid slope	3. concave	3	25- 50%	37.5%
4. lower slope	4. undulating	4	50- 75%	62.5%
5. bench or flat		5	75- 95%	85.0%
6. streambottom		6	95-100%	97.5%

TRANSECT E

YOPR-RHTR

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location

Type Popr-Rhtr
Stand No. or cluster BELT 1-20
Location
Date 9/8
Worker(s) [illegible]
Page ____ of ____
Photo # 9,10

Slope (%) 44 %
Aspect S245 W
Soil
Elevation 5640
Topography 3
Configuration 3
Range condition
Range trend

Line runs N 10° W

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	10	8	50	-	-	[illegible]	-	-	16	5	35	23	12	8	32	18	-	-	-	-	10.85/55
Rock	5	2	-	-	.	6	6	-	8	45	51	12	7	2	[illegible]	23	19	-	-	-	9.8/65
Litter	84	[illegible]	50	[illegible]	40	44	41	[illegible]	75	45	13	[illegible]	80	[illegible]	[illegible]	-	81	100	100	100	75.15/95
Lichens	T	T	-	-	-	2	3	-	T	5	2	4	T	2	3	4	-	-	-	-	1.25/55
Moss	0	0	-	-	-	0	-	-	-	-	0	1	0	1	0	-	-	-	-	-	.1/10
Agsp	8	T	-	-	2		-	-	T	15	11	10	4	41	4	7	-	7	10	5	6.05/70
				-			-	-	-	-	-	-	-	-	-	-	-	-	-		
[illegible]	3	4	-	-	.	-	-	-	-	-	-	-	-	-	-	10	-	-	-		.85/15
Poa [illegible]	9	44	11	9	38	[illegible]	17	14	23	T	-	-	-	-	-	5	25	3	11	19	11.48/75
[illegible]	-	4	-	-	-	-	-	-	6	2	-	-	-	-	-	-	-	-	-		.6/15
[illegible]			4	-	-	-	-	-			-	-	-	-	10	-	-	-	-		.95/10
Pogr											3	4	-	-		-	-	-	-		.35/10
Agcr	1	-	-	-	3	1	-	-	3	-	-	-	-	-	-	-	-	2	T		.53/30
Chvi	3	10	5		-		-	7	4	.	-	T	4	-	8	13	8	22	T		3.93/60
Tedi	7	-	-	.	-	.	-	-	-	-	-	2	-	3	-	-	-	-	-		.45/15
Lipe	-	-	1	-	-	.	-	1	1	-	-	-	.	1	.	-	-	-	-		.2/20
Cear			[illegible]		-	.	-	-	-	-	-	-	.	-	.	-	-	-	-		.15/5
Clematis				7	-	.	-	-	.	-	-	-	.	-	.	-	-	-	-		.35/5
[illegible]					2	-	-	-	-	-	2	-		-		-	-	-	-	1	.25/5
[illegible]							1	-	-	-	-	-		-		-	-	-	-		.05/5
LePo									T	-	T	-	-	-		-	-	-	-		.05/10
[illegible]											T	-	.	-		-	-	-	-		.03/5
PsCS												5	-	-		-	-	-	-		.25/5
Bal sag													26	-	-	-	-	-	17		2.15/10
Sici														1	.	-	-	-	-		.05/5
~~Agcr~~																2	-	-	-		.1/5
Prvi								-	-	-	-	-	-	-	-	-	-	-			1.3/10
[illegible]						[illegible]	-	-	-	4	-	-	-	-	-	10	T	-		1	1.03/30
Amal	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		.2/5
Syoc	18	1	-	25	16	-	2	-	-	-	-	-	-	-		-	3	-	3	5	4.55/40
Rhtr	7	T	-	10	5	5	5	1	T	-	-	5	6	8	-	-	16	8	39	15	6.95/75

Veth

Topography:	Configuration:
1. ridge	1. convex
2. upper slope	2. straight
3. mid slope	3. concave
4. lower slope	4. undulating
5. bench or flat	
6. streambottom	

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT F

AGSP-RHTR

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location

Type: Agsp-Rhtr	Slope (%): 75%
Stand No. or cluster: ~~BFIT 34~~ 24	Aspect: S26°3W
Location:	Soil:
Date: 8/8	Elevation: 3620
Worker(s): LL; DB	Topography: 4
Page ___ of ___	Configuration: 1
Photo #: 14,15 (Roll 1)	Range condition:
	Range trend:

Line runs S 30°E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	12	15		21	5	46	2	19	3	11	16	7	33	11	27	[illegible]	22	5	2	[illegible]	16.45/100
Rock	19	11	14	[illegible]	53	18	35	3	42	22	66	18	[illegible]	10	34	27	[illegible]	75	23	45	39.75/100
Litter	59	81	23	72	[illegible]	36	3	78	[illegible]	64	18	71	[illegible]	77	24	[illegible]	10	-	2	-	42.6/90
Lichens	T	4	T	[illegible]	T	T	-	-	1	2	-	1	T	2	-	-	T	-	4	-	0.88/65
Moss	-	-	-	-	-	-	-	-	-	T	-	-		-		-	-	-	-	-	0.03/10
Agsp	3	16	7	34	11	3	4	-	18	35	2	18	23	8	2	2	6	-	3	1	9.55/90
Brja	8	-	-	-	2	-	3	4	3	-	5	2	T	1	7	T	-	-	-	-	1.6/55
Poco								17	3	-	2	5	14	3	4	5	-	-	-	-	2.65/40
[illegible]	2	-	-	-	-	1	-		-	-	-	-	3	7	-	19	-	-	-	-	1.6/25
[illegible]	3	-	-	1	3	-	-		-	-	-	-	-	-		-	2	-	-	-	0.35/15
[illegible]			1			-	-		-	-	-	-	-	-	-	-	-	-	-	-	0.05/5
[illegible]	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15/5
Lede	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	0.10/10
[illegible]					4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2/5
Trdu					2	1	-	-	T	2	-	-	-	-	-	-	-	-	-	-	0.28/20
Thermopsis												4	1	-	3	-	3	-	-	-	0.8/20
Grsq										2	-	-	-	-	-	-	-	-	-	-	0.1/5
Veth															3	-	-	-	2	-	0.25/10
~~Lase~~																				4	0.20/5
[illegible]								1	3	8	-	7	2	2	14	-	-	-	3	-	2.0/40
Boar													[illegible]	4	-	2	-	-	-	-	0.55/10
Prvi								-	-	-	T	-	-	-	-	-	2	-	-	-	0.13/10
[illegible]	-	7	1	-	9	8	-	-	-	1	-	-	-	-		3	-	-	-	-	1.45/30
Syx[illegible]	3	4	-	-	-	-	-	-	3	4	-	3	2	13	-	3	4	-	-	-	1.8/40
[illegible]		3	-	3	-	-	-	24	11	-	-	-	-	-	-	-	-	-	-		2.65/20

Topography:	Configuration:	Coverage Class	Range	Midpoint
1. ridge	1. convex	1	0- 5%	2.5%
2. upper slope	2. straight	2	5- 25%	15.0%
3. mid slope	3. concave	3	25- 50%	37.5%
4. lower slope	4. undulating	4	50- 75%	62.5%
5. bench or flat		5	75- 95%	85.0%
6. streambottom		6	95-100%	97.5%

TRANSECT 6

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

ion of 6cb Plots
NW Sec 6 T18N R5E
NW Sec 6 T18N R5E
NW Sec 7 T18N R5E

Type Popr- Bhtr
Stand No. or cluster ST. 7-17 47, 46
Location NWNW Sec 7 T18N R5E
Date 9/9
Worker(s) [illegible]
Page ____ of ____
Photo # 26,27

Slope (%) 32%
Aspect S26W
Soil
Elevation 4000
Topography 3
Configuration 4
Range condition
Range trend

[illegible] 1105 N2E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL	
Bare ground	10	–	[illegible]	[illegible]	38	70	1-	75	–	27	18	11	31	[illegible]	10	[illegible]	18	[illegible]	11	–	24.2	85
Rock	–	–		2	[illegible]	20	T	14	–	–	–	–	–	–	–	–	T	–	–	–	2.15	30
Litter	90	[illegible]	[illegible]	62	[illegible]	9	[illegible]	11	100	71	[illegible]	8	[illegible]	[illegible]	[illegible]	58	80	[illegible]	58	[illegible]	69	95
Lichens	–	–		T	1	T	–	–	–	–	–	–	–	1	–	–	T	–	–	–	0.18	25
Moss	–				0	–	–	–	–	–	–		–	–			–	–		–	0	0
Popr	12	20	45	11	–	–	–	–	–	5	12	15	8	[illegible]	[illegible]	[illegible]	7	13	[illegible]	–	10.1	70
Agsm	1	1	–	1	3	3	21	1	1	2	–	[illegible]	–	–	–	–	6	2	–	–	2.1	55
Agsp	·	3	–	3	–	–	–	5	5	–	–	–		–	–	–	–	–	–	–	0.8	20
[illegible]				2	2	–	–	–	–	–	13	–	6	11	5	V	5	–	–	–	3.05	45
Cimo					1	2	–	1	–	–	–		–	–		–	–	–	–	–	0.2	15
Beja						–	4	–	1	1	–		–		–	–	–	–	–	3	0.45	20
Bote								1	–	–	–		–			–	–	–	–	–	0.05	5
Stco								2	–	–	–	–	–	–			–	–	–	–	.15	5
Brte																				1	0.05	5
[illegible]	7	–	–	–	–	–	–	–	1	–	–	–	1	3	–	T	–	–	3	–	.75	25
[illegible]	7	–	–	–	1	1	2	T	–	–	–	1	T	–	–	–	–	–	–	–	0.4	45
[illegible]	3	–	–	T	–	–	2	–	–	–	–	1	–			–	–	–	–	–	0.28	15
~~Antennaria spp~~	–	12	[illegible]	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	0.75	15
[illegible]				2			–	–	–	–	–	–	–	–		–	–	–	–	–	0.1	5
Saimi				2			–	–	–	–	–	–	[illegible]	7	2	2	–	–	–	–	0.6	25
[illegible]				1	3	1	–	4	–	–	–	–				–	–	–	–	–	0.45	20
[illegible]					5	–	–	1	–	–	–	–				–	–	–	–	–	0.3	10
[illegible]					1	–	–	–	–	–	–	–	–			–		–	–	–	0.05	5
[illegible]						1	–	1	–	–	–	–	–			–	–	–	–	–	0.1	10
[illegible]								3	–	1	1	–	8	·	1	–	–	–	1	–	0.75	30
Gaar									3	–	1	–			–	–	–	–	–	5	0.4	10
Lup. spp											1	–	–	–	–	–	1	–	–	–	0.1	10
S. B											13	2	3	2	–	–	–	T	–		1.0	25
Crin													3	7	14	1	1	–	–		1.3	25
Arfr																	1	–	–		.05	5
[illegible]				2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	5
														26	–	–	–	–	–	–	1.2	5
Chvi				5	1	–	4	–	4	–	–	–	–	–	–	–	–	–	–	–	0.7	20
Rosa	3	14	9	6	4	T	–	–	–	–	6	1	3	2	–	7	4	1	–	–	2.75	65
Syal	T	10	10	–	–	–	–	–	–	–	9	2	5	–		–	–	–	T	–	1.85	35
All						24		77	23	–	–	–				–	–	–	–	58	9.1	20

9LL, Gr..., Ardr

Topography:	Configuration:
1. ridge	1. convex
2. upper slope	2. straight
3. mid slope	3. concave
4. lower slope	4. undulating
5. bench or flat	
6. streambottom	

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT H

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Pile location
Sc 7 T13N R5E

Type Popr-Syoc
Stand No. or cluster STKT 7-45
Location SESW Sc 7 T13N R5E
Date 9-9
Worker(s) OB, LL
Page ____ of ____
Photo # 31 32

Slope (%) 25%
Aspect N 70 E
Soil ____
Elevation 3950
Topography 4
Configuration 1
Range condition ____
Range trend ____

Line runs N32°W CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	10	8	7	20	5	7	7	4	2	6	10	-	-			2	-	-	-	-	4.4/60
Rock	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-		-	0/0
Litter	87	89	92	77	95	92	93	96	97	94	89	100	100	100	100	99	100	100	[illegible]	100	94.65/100
Lichens	T	2	-	-	0	1	-	-	-	-	-	-				-	-	-	-	-	0.15/20
Moss	2	1	1	3	2	-	-	-	1		1	-	-	-		-	-	-	-	-	0.45/35
Popr	36	12	42	19	55	59	78	[illegible]	55	85	79	84	86	54	21	38	90	44	42	46	55.6/100
Agsm	1	2	-	3	2	6	2	2	1	1	3	1	-		-	-	-	-	T	-	1.28/60
STVI	2	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	0.1/5
Caol				6	-	4	-	-	-	-	-	2	-	-	-	-	-	-	-	-	0.6/15
Acal	1	-	-	-	-	-	-	-	-	-	-	-	2	7	-	-	3	1	-	L	0.75/30
Acmi		1	-	-	7	2	-	1	-	-	2	-	-	-	-	-	-	-	-	7	1.0/20
Chvi		5	-	3	T	-	-	-	-	-	-	-	-		-	-	-	-	-	-	1.43/15
Lele			T	-		1	T	-	-	-	-	-	-		-	-	-	-	-	-	0.15/15
[illegible]					2	-	-	-	-	-	-	-	-		-	-	-	-	-	-	0.1/5
~~[illegible]~~						~~1~~	~~-~~														~~0.05/5~~
? [illegible]											4	-	-	-	-	-	-	-	-	-	0.2/5
[illegible]														2	1	2	-	-	-	-	0.25/15
Cyof																5	-	-	-	-	0.25/5
[illegible]																		2	-	-	0.1/5
Arlu																			11	3	0.7/10
arfr			1	3	-	3	-	3	T	-	-	-	-	-	-	-	-	-	-	-	0.53/25
Syoc	2	3	2	1	-	-	-	5	8	8	13	28	23	15	55	57	6	10	9	-	12.85/85

Bogr.

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

Transect I

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Type Popr-Agsm
Stand No. or cluster STKT 1-36
Location SWNE Sec 36 T19N R4E
Date 9/10
Worker(s) [illegible]
Page ______ of ______
Photo # 10,11

Slope (%) ridge top
Aspect [illegible]
Soil
Elevation 3700-3720
Topography 1
Configuration 4
Range condition
Range trend

[illegible]

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	41	[illegible]	54	[illegible]	78	43	53	[illegible]	7	8	17	48	14	[illegible]	[illegible]	39	[illegible]	15	23	[illegible]	37.85/100
Rock	15	25	9	4	2	3	7	7	–	–	–	–	15	6	–	6	22	55	[illegible]	[illegible]	10.4/80
Litter	41	[illegible]	35	[illegible]	19	[illegible]	[illegible]	20	[illegible]	[illegible]	83	[illegible]	10	[illegible]	[illegible]	55	33	30	[illegible]	[illegible]	51.05/100
Lichens	3	2	T	–	7	–	–	–	–	–	–	[illegible]	1	–	T	–	–	–	T	–	0.5/40
Moss		–		–	–	–	–	–	–	–	–	–	–	–	[illegible]	–	–	–	–	–	0.23/10
[illegible]	3	–	–	[illegible]	2	1	[illegible]	1	7	1	5	2	–	–	1	4	5	2	[illegible]	11	2.75/80
Ag[illegible]	2	3	[illegible]	[illegible]	–	2	–	3	4	T	–	–	–	–	–	3	–	1	–	T	2.15/55
[illegible]	6	[illegible]	–	[illegible]	17	–	–	[illegible]	–	–	–			–	–	–	3	–	11	2	2.43/40
Cafi	–	6	14	3	–		–	–	–	–	–		–	–	–	–	–	–	–		1.15/15
[illegible]	–	5		–	1	–	–	–	–	–				–	–	–	–	–	–		0.3/10
[illegible]	–	–	–	1	–	–	–	–	–	–			–	–	–	–	–	–	–		0.05/5
Popr						3	4	2	1	1	5	4	1	3	–	–	1	3	4		1.55/60
[illegible]						9	4	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	11	26	3	T	2	–		6.73/65
[illegible]	1	–	–	1	–	–	–	–	–	–	–			–	–	–	–	–	–		0.25/10
Grsq	1	–	–	–	–	–	–	–	–	–	–			–	–	–	–	–	–		.75/20
[illegible]	1	–	–	–	–	4	–	–	–	–	–				–	–	–	–			0.25/10
V[illegible]		–	–	–	–	–	–	–	[illegible]	–	–				–	–	–	–			0.25/10
h[illegible]		11	–	–	–	6		1	–		–				–	–	–	–			0.85/15
[illegible]		1	–	–	–	–	–				5	1		[illegible]	–	4	5	–		3	3.8/45
[illegible]			T	–	–	–	–				–	–					–	–			0.05/5
[illegible]											–	–	–				–	–			0.03/5
[illegible]							–	1		–	1	4	T			–	2	–			0.43/25
[illegible] fa							2	–	–	–	–	–	1		–	–	–				0.15/10
[illegible]							1	4	–	–	–	–	4			–	1				0.5/20
[illegible]									6	–	3	–	–	T			5	–			0.73/20
[illegible]											–	–					–				~~0.25/10~~
[illegible]											–	4			–	–	–	1			0.25/10
[illegible]											–	3			–	–	–				0.15/5
[illegible]			[illegible]	–	[illegible]	–	1	–		–	–	–	–	–	5	–	3	–	–		0.75/25
[illegible]															4		–	–	–		0.2/5
[illegible]																	3				~~0.15/5~~
[illegible]																	3	3	–		0.3/10
[illegible]													4					x			~~0.15/15~~

Mesa

GLLe

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

Utilization ≅ 50%

Transect J

Pile Location

SWSE Sec 36 T19N R4E

NESWSec36 T19N R4E

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Type Agsp-Popr
Stand No. or cluster STAT 7-37,38
Location NESW Sec 36 T19N R4E
Date 9/10
Worker(s) DR, LL
Page ____ of ____
Photo # 13, 14

Slope (%) 34%
Aspect N71°E
Soil ____
Elevation 3780
Topography 2
Configuration 4
Range condition ____
Range trend ____

Line [illegible] S13°E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	14	14	17	12	17	37	41	36	48	7	24	44	14	5	28	31	9	18	11	7	20.7/100
Rock	6	—	5	3	2	2	4	1	2	—	2	3	—	—	5	2	—	T	3	T	2.2/65
Litter	83	86	77	55	51	51	52	62	40	93	74	83	86	95	[illegible]	66	80	81	85	93	76.6/100
Lichens	1	—	T	—	—	—	—	T	—	—	—	—	—	—	3	1	—	—	—		0.3/25
Moss		—	—		—	—	—	—	—	—	—	—	—	—	—		2	—	1	—	0.15/10
[illegible]	14	13	16	13	2	T	3	3	—	9	10	15	T	—	—	—	—	7	9	4	4.93/65
[illegible]	1	2	3	3	28	14	5	13	8	21	9	11	20	31	12	28	10	25	8	18	13.5/100
[illegible]		1	2	2	—	—	1	4	3	2	5	3	3	4	7	—	—	—	1	1	1.95/70
[illegible]			2	—	—	2	3	7	2	1	—	—	—	6	2	2	4	—	—	—	1.25/50
CAMO																3	2	—	—	—	0.25/10
Lede			T	—	—	—	—	T	—	—	—	1	—	1	2	2	4	1	T	T	0.68/50
[illegible]	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.05/5
[illegible] spp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.025/5
[illegible]			1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	0.1/40
Lupinus spp				9	—	—	T	—	—	T	—	—	—	—	—	—	—	—	—	—	0.5/15
[illegible]					T	11	3	2	1	—	—	—	—	1	4	3	4	—	—	—	1.1/45
[illegible]						T	—	—		—	—	—	—	—	—	—	—	—	—	—	0.03/5
[illegible]								9	—	8	4	—	—	—	—	—	—	—	—	—	1.05/15
[illegible]												—	2	2	—	—	—	—	—	—	0.25/10
[illegible]												—	5	—	—	—	—	—	—	—	0.25/5
[illegible]												—	—	—	—	—	3	—	—	—	0.15/5
[illegible]												—	2	—	—	—	—	—	—	—	0.1/5
[illegible]	4	1	—	—	[illegible]	—	—	6	—	—	—	T	—	3	—	—	—	—	—	T	1.05/35
[illegible]		4	3	4	—	—	—	—	—	—	—	—	3	—	13	2	2	4	8	1	2.4/70

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

Transect K

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

6 PILE

NNE Sec 14 T18N R4E

Type Aasp-Boar	Slope (%) 25%
Stand No. or cluster 7-20	Aspect S265W
Location NW SE Sec 14 T18N R4E	Soil
Date 9/10	Elevation 3920
Worker(s) DB LL	Topography 4
Page ___ of ___	Configuration 1
Photo # 16, 17	Range condition
	Range trend

Line runs [illegible]

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	10	24	44	14	20	18	9	5	43	35	35	5	34	14	12	23	36	38	13	19	22.55/100
Rock	28	7	16	T	6	6	5	T	5	15	T	-	4	4	3	4	4	6	4	2	6.08/95
Litter	59	68	39	85	74	73	84	73	50	47	62	95	60	80	85	71	59	55	51	77	69.95/100
Lichens	5	1	T	-	-	3	2	T	2	3	T	-	1	1	-	2	T	1	2	T	1.28/80
Moss			-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	0.05/5
Aasp	14	5	1	11	9	6	16	11	6	11	8	2	12	10	11	14	15	10	16	2	10.7/100
[illegible]	3	10	7	-	19	11	5	12	10	2	11	5	T	T	4	1	6	4	5	6	6.45/95
[illegible]	1	-	4	5	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	0.53/20
[illegible]		6	-	1	-	17	3	7	7	12	18	2	4	9	2	5	7	34	3	21	8.8/85
Popr		1	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.25/15
[illegible]			2	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.25/15
Agsm			1	T	-	-	-	-	-	-	-	-	1	-	4	-	8	-	1	-	2.55/35
[illegible]				2	-	-	-	-	5	-	-	3	6	-	7	5	-	-	T	-	0.08/10
Cael							1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.43/35
																					0.05/5
GaCO																					
Chwi		8	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	0.05/5
[illegible]		2	3	-	-	-	-	-	2	4	8	-	T	5	-	3	4	2	13	7	3.33/55
Acmi	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0.25/10
Spca	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1/5
[illegible]	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05/5
[illegible] spp.		T		10	4		7	2	-	-	16	-	-	-	-	-	-	-	-	-	0.6/10
Casa			1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.09/35
Lede				7	1	1	-	2	1	1	T	-	-	2	1	1	-	3	1	-	0.2/10
Trdu				5	3	-	-	T	3	-	-	-	5	-	-	3	-	3	8	2	1.23/65
[illegible]						5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.63/45
[illegible]								1	-	-	-	-	-	-	-	-	-	-	-	-	0.25/5
[illegible]								-	3	1	-	-	8	-	-	2	5	-	-	-	0.05/5
Erigeron								-	2	-	-	-	-	-	-	-	-	-	-	-	1.05/30
[illegible]										2	-	-	-	-	-	-	-	-	-	-	0.1/5
[illegible] spp.											-	1	-	-	-	-	-	-	-	-	0.1/5
Lipo														4	-	-	-	-	1		0.05/5
[illegible]		-	-	5	6	-	-	3	1	3	6	-	-	2	15	11	-	2	3	2	0.25/10
Phho													-	-	-	-	-	-	-	-	3.2/70
Symi																		2	-		0.1/5
																			-		0.1/5
Ch[illegible]c																			-		0/0
								1	-	-	13	-	-	-	-	-	-	-	-		0/0
																					0.7/10

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT L

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location
ESW Sec2 T19N R4E
NW Sec36 T19N R4E
NE Sec25 T19N R4E

Type Popr-Sudc
Stand No. or cluster STRT 7-45, 28, 29
Location NESW Sec 25 T19N R4E
Date 4/10
Worker(s) LL, DB
Page ____ of ____
?→Photo # 2, 3

Slope (%) 16%
Aspect ~~S35 W~~ S235 W
Soil
Elevation 3640
Topography 4
Configuration 4
Range condition
Range trend

Lin cuns S46°W

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	12	23	16	5	17	4	-	-	-	-	7	4	20	14	-	-	-	-	-		7.5/50
Rock	T	2	1	-	-	-	-	-	-	-	-	.	25	3	9	-	-	-	-		2.03/30
Litter	78	74	82	95	93	96	100	100	100	100	93	[illegible]	14	82	[illegible]	[illegible]	[illegible]	[illegible]	100	100	89.2/100
Lichens		T	1	-	-	-	-	-	-	-	-	-	7	T	-	-	-	.			0.13/20
Moss		-	-	-	-	-	-	-	-	-	-	-	-	.	-	-	-	.			0/0
Ca el	2	1	-	T	4	2	-	-	-	5	2	-	-	-	1	-	2	8	3	3	1.73/60
Agsm	5	-	3	8	1	3	3	5	2	-	-	[illegible]	[illegible]	[illegible]	8	-	4	2	-	2	3.1/75
Stco	8	8	4	-	-	-	-	-	-	-	-	4	-	10	-	-	-	-	-		3.2/25
An so	2	-	-	-	-	-	-	-	-	-	-	3	T	4	-	2	-	-			0.63/25
Bo[illegible]			3	-	3	-	6	-	-	T	-	-	1	1	7	7	9	8	5	3	2.35/60
popr				11	-	T	-	7	18	32	27	-	-	.	18	21	-	-	12	2	12.53/50
st[illegible]												7	14	-	-	-	14	21	T	2	3.58/30
Bogr													3	-	-	-	-	-	-	-	0.15/5
Lipe	11	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	.	-	-	0.7/10
[illegible]	7	-	-	5	-	-	-	-	-	-	-	-	-	3	.	-	.	-	-	-	0.75/15
Sa[illegible]	1	-	-	-	-	-	-	-	-	-	-	-	-	.		.	.	.	-	-	0.05/5
Lede		1	5	2	-	1	1	4	-	-	-	-	2			T	.	-	-		0.63/40
Trdu			6	-	-	-	-	-	-	-	-	-	-			.	.	.	.		0.3/5
Li[illegible]			4	-	12	-	-	-	-	-	-	-	-			.	.	-	.		1.05/10
Silb								4	-	-	-	-	-	.			.	.	.		0.2/5
Assa									10	T	-	T	-	.	2			-	10	-	0.93/25
Arlu												T	-	.	.		-	T	-		0.05/10
Ca micro													1	-			-	-	-	-	0.05/5
Os pu														T	-	-	.	-	-	-	0.03/5
Ch vi														T	-	-	-	-	.	-	0.03/5
GLic																3	2-	11a	1	-	2.1/20
Ar[illegible]	4	-	2	3	-	-	-	-	-	-	-	-	-	.		-	-	-	-		0.45/15
Sudc			2	5	13	52	15	3	3	29	4	-			.	.	.	.	-		7.85/45

Mammala
u
GLic
Pepu

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT M

Location
SESW Sec 18 T19N R5E
ENW Sec 19 T19N R5E
ENW Sec 19 T19N R5E

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Type: Popr-Agsp
Stand No. or cluster: V 7-13, 14, 15
Location: SESW Sec 18 T19N R5E
Date: 9/11
Worker(s): [illegible]
Page ___ of ___
Photo #: 9, 10

Slope (%): 65%
Aspect: N 41° E
Soil: ___
Elevation: 3540
Topography: 3
Configuration: 4
Range condition: ___
Range trend: ___

[illegible] 544

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	–	2	6	.	11			5	3	–	7	4	–	.		.	2	7	5	[illegible]	3.75/65
Rock	–	.	.	9	.			17	–	.	5	–	1	.		–		–	.		1.75/20
Litter	100	95	[illegible]	82	89		100	75	[illegible]	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	94.35/95
Lichens	–	.	–	.	–	–	–	3	–	–	1	.	.	.		.		.	–	.	0.35/15
Moss	–	.	–	–	–	.		–	–	–	–	–	.	.			.	.		–	0/0
																				–	
[illegible]	3	[illegible]	[illegible]	21	[illegible]		7	34	9	11	7	[illegible]	13	9		25	20	8	–	1	15.0/95
[illegible]	2	[illegible]	8	[illegible]	1	–	5	4	[illegible]	11	10	–	[illegible]	1	.	5	11	[illegible]	[illegible]	[illegible]	7.25/95
[illegible]	–	3	2	1	.	–	2	[illegible]	2	3	5	–	.	7	1	1	2	7	[illegible]	3	2.43/85
[illegible]			T	–	–	–	–	–	–	T	–	–	.	–	–	–	–	–	1	–	0.1/15
																1	4	–	10	–	1.0/15
[illegible]																			1	–	0.05/5
[illegible]		[illegible]			–	–	–	5	5	–	2				–	–	15	5	–	2	1.7/35
						–	–	–			–					–					[illegible]/5
[illegible]						–	–	–	–		–				.	–		.	4		0.1/15
[illegible]			25		–	–	–	.	–	–	–	.			.	–		.			1.25/5
[illegible]			–	4	–	–	–		–		–					–			.		0.2/5
						15	–	–	–	–	8	20			.	.	.				2.4/25
[illegible]							11	–	–	–	–	–			.	–					0.55/5
														[illegible]	.	–		[illegible]	.		0.25/10
~~[illegible]~~														[illegible]		.			.		0.15/5
																					~~0.05/5~~
Potentilla																	1	–	–		0.05/5
																			5	2	0.35/10
[illegible]																			–	3	0.15/5
[illegible]									2	[illegible]	10	–				.	.		–	–	2.75/25
[illegible]																		[illegible]	–	–	0.35/5
[illegible]																				4	0.45/5
														.	–	.			–	–	0.6/5
										13	11		11	[illegible]	.	.			–	–	1.65/25
[illegible]					–	[illegible]	[illegible]	–	–	[illegible]	–	–	[illegible]	[illegible]	.		.		–	–	6.8/20
[illegible]			–	[illegible]		–	–	–	–	–	–	5		–		[illegible]	1		–	–	1.3/20
	[illegible]	11	–	–	[illegible]		+	–	–	–	–	–		–		–	–		–		1.18/25
	[illegible]	5	–	–		[illegible]	[illegible]	[illegible]	–	–	–			–	[illegible]				–	3	1.85/35

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

Utilization ≅ 20% TRANSECT N

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location.
NWNW SEC 20 T1N R5E
NE SEC 19 T1N R5E
SE SEC 18 T1N R5E
SE SEC 18 T1N R5E

Type Agsp-Rhtr
Stand No. or cluster CV7-7,9,10,11
Location NENE SEC 19 T1N R5E
Date 9/11
Worker(s) DB, LL
Page ____ of ____
Photo # 15,16

Slope (%) 47%
Aspect S23BW
Soil
Elevation 3620
Topography 4
Configuration 1
Range condition
Range trend

Line runs S40° E

CANOPY COVERAGE

SPECIES	TOTAL
Bare ground	12.2/90
Rock	46.5/95
Litter	37.35/95
Lichens	3.73/90
Moss	0.15/15
[illegible]	11.9/90
[illegible]	0.95/60
[illegible]	1.23/45
[illegible]	1.0/10
[illegible]	1.55/35
[illegible]	0.35/15
Stvi	0.25/10
[illegible]	1.83/70
[illegible]	0.7/10
[illegible]	0.95/15
Thermopsis	0.25/10
[illegible]	0.2/5
[illegible]	0.025/5
[illegible]	0.05/5
[illegible]	0.4/10
[illegible]	0.2/5
[illegible]	0.15/5
[illegible]	0.6/10
[illegible]	7.0/10
[illegible]	0.65/15
[illegible]	1.2/30

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

Utilization ≅ 5%

TRANSECT D

Location
SENESec 18 T19N R5E
SENWSec 18 T19N R5E
NWNWSec 18 T19N R5E

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Type Agsp-Rhtr
Stand No. or cluster CV-12B, 43
Location SENW Sec18 T19N R5E
Date 9/17
Worker(s) DB LL
Page ____ of ____
Photo # 22

Slope (%) 50%
Aspect S85°W
Soil
Elevation 3540
Topography 3
Configuration 1
Range condition
Range trend

Line runs S83°E CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	18	–	–	16	6	–	11	10	–	–	65	19	10	4	3	65	19	6	7	37	14.2/25
Rock	73	[illegible]	75	13	11	84	8	15	8	58	3	8	12	18	35	20	16	29	16	21	30.6/100
Litter	–	28	10	37	83	5	78	74	22	35	81	74	19	69	55	14	52	6	72	33	50.25/95
Lichens	19	8	15	11	–	11	–	T	2	7	T	T	1	9	7	1	3	10	5	11	5.73/90
Moss	–		–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	0.15/5
[illegible]	1	6	4	21	10	2	15	11	15	22	1	4	12	36	10	1	4	13	22	9	11.9/100
Brga		4	–	–	9	4	1	8	–	–	–	–	–	–	–	–	–	–	1	3	1.0/30
Agsm			1	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–		0.05/5
Brar			2	T	T	6	21	–	–	–	21	8	11	–	19	17	–	–	T		4.48/55
Arlo				5		–	–	–	–	–	4	22	13	–	–	–	9	20	–	3	4.05/35
Brte						1	–	–	8	–	3	–	–	–	T	–	–	–	–		0.33/20
[illegible]	–	T	–	–	–	–	–	–	–	–	–	–	–	1	–	T	–	–	1	–	0.33/30
[illegible]		1	–	–	–	–	–		–	–	2	–	–	–	–	–	–	–	–	–	0.15/10
[illegible]				11	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	0.3/15
Silo					7	–	–	–	–	–	–	–	–	–		–	–	–	–	–	0.025/5
[illegible]					–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.025/5
[illegible]					1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.05/5
[illegible]							[illegible]	[illegible]	–	–	–	–	–	–	–	–	–	–	–	–	1.7/10
Gesp								1	–	–	–	–	–	–	–	–	–	–	–	–	0.05/5
[illegible]								1	–	–	–	–	–	–	–	–	–	–	–	–	0.05/5
[illegible]									3	–	–	–	–	–	–	–	–	–	3	–	0.15/10
[illegible]							2	–	–	–	1	14	7	1	4	3	5	8	4	2	2.55/55
Veth											8	–	–	–	–	–	–	–	–		0.4/5
[illegible]	[illegible]	12	7	–	18	8	–	–	48	–	–	–	–	–	–	–	–	–	–	–	4.7/30

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

Debi

Pile Location
SW NE Sec 13 T19N R4E
NW SW Sec 13 T19N R4E
E NE Sec 23 T19N R4E
Shtr - Agsp

TRASECT P

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Type: PopC - Agsp - Shtr	Slope (%): 41 %
Stand No. or cluster: 7-27,48,49	Aspect: S55W
Location: NWNW Sec 24 T19N R4E	Soil:
Date: 9/10	Elevation: 3600
Worker(s): DB LL	Topography: 3
Page of	Configuration: 4
Photo #: 7,8 roll 2	Range condition:
	Range trend:

Line runs N8°W

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	17	9	2	28	5	6	-	26	[illegible]	-	[illegible]	25	16	[illegible]	7	-	-	21	-	7	14.15/75
Rock	14	1	[illegible]	2	19	-		4	1	-	11	31	11	14	[illegible]	-	[illegible]	-		-	16.35/25
Litter	66	[illegible]	87	70	74	20	100	64	[illegible]	100	[illegible]	40	[illegible]	26	22	-	13	[illegible]	16	[illegible]	71.75/100
Lichens	3	1	T	-	2	[illegible]	-	1	-	-	1	6	1	T	5	-	2	-	-	3	1.68/65
Moss	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0/0
[illegible]	1	-	-	1	1	-	-	-	1	T	-		-	1	-	-					0.28/30
Agsp	1	14	-	8	24	8	-	12	8	1	31	6	17	[illegible]	15	21	5	21	[illegible]	[illegible]	7.7/90
[illegible]	15	7	14	17	13	[illegible]	25	9	5	6	1	5	[illegible]	13	-	6	2	15	[illegible]	6	10.6/95
[illegible]		2	2	-	-	-		-	-	-	-	-	-	-	-	-		2	-	11	0.85/20
Drja							T	-	-	2	-	-	-	-	-	-	-	-	-		0.13/10
[illegible]		1	-	-	5	-	-	-	1	3	-	-	-	-	-	-	-	[illegible]	-		0.8/25
[illegible]		2	-	2	-	-	-	-	5	-	-	7		-	-	-	-	-	-		0.9/20
[illegible]				T	-	-	-	-	-	-	-	2		-	-	-	-	-	-		0.13/10
Asca				-	4	2	-	1	-	-	-	-		-	-	-	-	-	-		0.35/15
[illegible]								4	7	-	1	-	T		1	-	-	-	-		0.70/30
[illegible]											2	-	-		-	-	-	-	-		0.1/5
[illegible]												T	-	-	-	-	-	-	-		0.5/5
[illegible]												-	3	3	-	-	-	-	-		0.3/10
[illegible]																				-	0.15/5
[illegible]																				7	1.0/5
[illegible]						4	-	-	3	-	-	2	-	-	-	-	-	-	-		0.45/15
[illegible]												T	T	3	-	-	-	-	-		0.2/15
[illegible]								5	-	-	-	3	-	-	-	-	-	-			0.4/10
[illegible]			4		T	-	-	1	-	1	8	-	T	-	-	-	-	-	-		0.75/30
[illegible]	1	9	8	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1.18/20
[illegible]	1	3	5	3	8	-	-	-	-	-	2	-	4	[illegible]	1	-	-	4	-	-	2.45/55
[illegible]						20	5	-	-	-	-	-	-	-	-	5	-	-	4		5.8/20

?

Vu c
Arlo
Ciun

Topography:	Configuration:	Coverage Class	Range	Midpoint
1. ridge	1. convex	1	0- 5%	2.5%
2. upper slope	2. straight	2	5- 25%	15.0%
3. mid slope	3. concave	3	25- 50%	37.5%
4. lower slope	4. undulating	4	50- 75%	62.5%
5. bench or flat		5	75- 95%	85.0%
6. streambottom		6	95-100%	97.5%

THANSECT Q

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Location
SWSec 19 T19N R5E
NWSec 7 T19N R4E (stitches E)

Type PoPC-SWOL
Stand No. or cluster CV 7-16, 40
Location NWSW Sec 7 T19N R5E
Date 9/11
Worker(s) DB LL
Page ____ of ____
Photo # 3, 4

Slope (%) 46%
Aspect N6°E
Soil ____
Elevation 3520
Topography 2
Configuration 1
Range condition ____
Range trend ____

[illegible] runs S71°E

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	5	[illegible]	–	12		[illegible]	5	1	4	22	11	–	7	11	6	[illegible]	13	55	11	5	16.6/85
Rock	28	–	–	–		–	3	–	6	11	5	–	–	–	–	[illegible]	–	1	9	6	3.0/45
Litter	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100	[illegible]	[illegible]	[illegible]	[illegible]	37	[illegible]	90	40	79.1/100
Lichens	3	[illegible]	–	–		–	–	–	–	–	–	–	–	–	–	5	–	–	.	–	0.4/15
Moss		[illegible]	–	3		2	–	–	–	–	–	–	–	–	1	–	–	T	–	–	0.83/25
Ribes																				4	0.2/5
[illegible]	11	[illegible]	8	24	[illegible]	21	22	22	11	16	9	41	17	24	[illegible]	[illegible]	11	11	5	[illegible]	21.0/100
[illegible]	4	1	–	T	3	–	T	–	–	2	–	–	1	–	–	–	–	7	–		0.95/40
[illegible]					1	1	–	1	1	–	–	–	1	–	–	–	1	–	–	1	0.35/35
[illegible]	1	–	–	.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	.	1	0.10/10
[illegible]		3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	.	.	0.15/5
Feid		3	[illegible]	7	–	–	–	–	3	–	–	–	–	–	–	5	–	11	–		1.45/30
Agsp				T	T	–	–	19	4	2	.	1	2	–	2	–	–	–	.	12	2.05/45
[illegible]												2	–	2	[illegible]	8	–	–	–	–	0.6/15
ceor																		–	1		0.05/5
Taof																		3	.		0.15/5
arlu																	1	–	.		0.05/5
arde																	7	–	.	.	0.35/5
[illegible]	[illegible]	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–		–	0.25/10
[illegible]	21	–	–	4	–	2	–	–	–	–	–	–	–	–	2	1	–	–	–		0.65/25
C[illegible]		–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	0.25/5
[illegible]	1	.	–	–	–	–	–	–	–	–	–	–	–		.	–	–	–	–	–	0.05/5
[illegible]	1		–	–	–	–	–	–	–	–	–		–			–		–	–	–	0.05/5
[illegible]		.	–	–	–	[illegible]	4	–	–	–	–	T	3		–	–	–	1	–	–	0.63/30
[illegible]	1	[illegible]	.	–	–	–		–	–	–	–	–	–		–	–	–	–	–	–	0.45/10
[illegible]		[illegible]		–	–	3	–	5	2	–	–	5	2	6	–	2	1	–	–		1.5/45
[illegible]		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.2/5
[illegible]		3	[illegible]	9	[illegible]	–	2	10	1	14	27	13	1	18	14	12	5	10	2	–	8.95/85
Cisp			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1/5
[illegible]			1	.	.		–	–	–	–	1	–	3	3	.	–	–	–	–	–	0.4/20
[illegible]			.	.	9	.	–	–	–	–	–		–	–	–	–	–	–	–	–	0.5/10
[illegible]			.	–	.	.	2	–	3	5	–	–	1	3	–	2	6	–	5	1	1.4/50
[illegible]				1		.	–	–	–	–		–	–	–	–	–	–	–	–	–	0.05/5
[illegible]						–	13	–	–	–	–	–	–	–	–	–	–	–	–	.	0.65/5
ACth		–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	.	0.25/5
hrtr		[illegible]		–	–	–	–	–	–	2	1	–		–	.	–	–	–	1	2	0.55/25
[illegible]						5	.		–	–	–	–	–	–	.	–	–	–	–	–	0.25/5
[illegible]																4	–	3	8	–	0.75/15
[illegible]						2	–		–	–	–	–	–	–	–	–	–	–	–	–	0.10/5
[illegible]							–	[illegible]	5	–	–	–	–	–	–	–	–	–	–	–	0.4/10
[illegible]					1	–	2	[illegible]	[illegible]	8	4	–	–	11		1	–	–	10	9	2.05/45
[illegible]		1	1.	–	.	T	–	10	4	–	10	–	7	–	–	–	–	2	3		2.18/45

Topography:	Configuration:	Coverage Class	Range	Midpoint
1. ridge	1. convex	1	0- 5%	2.5%
2. upper slope	2. straight	2	5- 25%	15.0%
3. mid slope	3. concave	3	25- 50%	37.5%
4. lower slope	4. undulating	4	50- 75%	62.5%
5. bench or flat		5	75- 95%	85.0%
6. streambottom		6	95-100%	97.5%

TRANSECT 4

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

6 LOCATION
NENE Sec 7 T19N R5E
NWNE Sec 7 T19N R5E

Type Bear-Poor
Stand No. or cluster N 7- 41, 42
Location NWNW Sec 8 T19N R5E
Date 9/10
Worker(s)
Page of
Photo # 34, 35 roll 1

Slope (%) 26%
Aspect N32W
Soil
Elevation 3520
Topography 4
Configuration 4
Range condition
Range trend

CANOPY COVERAGE

SPECIES	PLOT NUMBER 1–20	TOTAL
Bare ground	[illegible]	21.6/100
Rock	[illegible]	14.95/90
Litter	[illegible]	47.95/100
Lichens	[illegible]	4.25/90
Moss	[illegible]	10.45/95
[illegible]	[illegible]	1.03/20
[illegible]	[illegible]	3.1/90
[illegible]	[illegible]	2.85/80
[illegible]	[illegible]	1.6/30
[illegible]	[illegible]	1.65/80
[illegible]	[illegible]	0.3/20
[illegible]	[illegible]	2.25/75
[illegible]	[illegible]	1.5/30
[illegible]	[illegible]	0.2/5
[illegible]	[illegible]	2.5/60
[illegible]	[illegible]	0.5/15
Le'de	[illegible]	1.35/65
[illegible]	[illegible]	0.85/55
Eri	[illegible]	0.88/40
[illegible]	[illegible]	0.25/15
[illegible]	[illegible]	0.2/10
[illegible]	[illegible]	0.05/5
[illegible]	[illegible]	0.23/25
[illegible]	[illegible]	0.25/10
[illegible]	[illegible]	0.1/5
[illegible]	[illegible]	0.15/5
[illegible]	[illegible]	1.45/45
[illegible]	[illegible]	0.18/15
[illegible]	[illegible]	0.08/25
[illegible]	[illegible]	0.25/10
[illegible]	[illegible]	1.65/70
[illegible]	[illegible]	1.0/10
P	[illegible]	0.15/15
[illegible]	[illegible]	0.28/15
[illegible]	[illegible]	0.2/10
[illegible]	[illegible]	0.55/20
[illegible]	[illegible]	0.05/5
[illegible]	[illegible]	0.4/5
[illegible]	[illegible]	0.58/30

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

TRANSECT S

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Stance Location

SWSec 32 T20N R5E

Type: Bogr-Stco	Slope (%): 16%
Stand No. or cluster: 1B 7-2	Aspect: N 337° W
Location: SWSW Sec 32 T20N R4E	Soil:
Date: 9/11	Elevation: 3465
Worker(s): [illegible]	Topography: 3
Page ___ of ___	Configuration: 4
Photo #: 7, [illegible]	Range condition:
	Range trend:

[illegible] N 76° [illegible]

CANOPY COVERAGE

PLOT NUMBER

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	[illegible]	[illegible]	[illegible]	[illegible]	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	27.4/100
Rock	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.48/90
Litter	[illegible]	[illegible]	[illegible]	73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	54	[illegible]	[illegible]	[illegible]	44.9/100
Lichens	2	[illegible]	4	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	11	3		[illegible]	[illegible]	5	4	[illegible]	10	1	4.9/95
Moss [illegible]	4	[illegible]		[illegible]	4	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	31	3	7	[illegible]	20.08/85
Bo[illegible]	3	5	[illegible]	5	[illegible]	10	1	1	1	2	[illegible]	[illegible]	[illegible]		1	2	[illegible]	[illegible]	1	[illegible]	3.68/100
B[illegible]	17	10	[illegible]	7	[illegible]	8	[illegible]	[illegible]	11	21	[illegible]	—	[illegible]	[illegible]	6	3	9	11	3	[illegible]	10.10/95
[illegible]				7	—	[illegible]	2	—	[illegible]	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	3	—	[illegible]	[illegible]	4.15/20
[illegible]		[illegible]	[illegible]	6	7	7	[illegible]	[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	—	[illegible]		4.33/90
						8	[illegible]	[illegible]	—	1	[illegible]	—	[illegible]	1	[illegible]	1	—	2	—		1.73/60
Hasp.																					0.15/5
asfa.					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		0.75/25
							[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	6	[illegible]		[illegible]		0.45/15
		[illegible]					[illegible]		[illegible]	1	1	2	[illegible]		[illegible]		[illegible]				0.4/30
																			1		0.05/5
ar[illegible]		1	—	—	[illegible]	2	—	[illegible]	2	—	[illegible]			[illegible]	—	—	—	[illegible]	—	—	0.5/25
[illegible]	15	7	9	[illegible]	[illegible]	2	[illegible]	9	7	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			7.3/95

Topography:

1. ridge
2. upper slope
3. mid slope
4. lower slope
5. bench or flat
6. streambottom

Configuration:

1. convex
2. straight
3. concave
4. undulating

Coverage Class	Range	Midpoint
1	0- 5%	2.5%
2	5- 25%	15.0%
3	25- 50%	37.5%
4	50- 75%	62.5%
5	75- 95%	85.0%
6	95-100%	97.5%

RANGE RESOURCE ANALYSIS
Field Data Sheet
(20 x 50 cm plot)

Type [illegible] site 7-4	Slope (%)
Stand No. or cluster	Aspect
Location [illegible]	Soil
Date	Elevation
Worker(s) [illegible]	Topography
Page ____ of ____	Configuration
Photo # 10	Range condition [illegible]
	Range trend

CANOPY COVERAGE

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Bare ground	[illegible]			[illegible]	[illegible]			65	38	56	10	4	4	27	43	30	5	[illegible]	8	[illegible]	26.[illegible]/[illegible]
Rock	[illegible]					[illegible]		5	2	[illegible]	75	90	6	8	7	[illegible]	t	2	[illegible]		14.[illegible]/100
Litter	[illegible]	[illegible]		[illegible]	[illegible]			27	58	11	12	4	55	67	46	[illegible]	16	80	[illegible]	[illegible]	56.3/100
Lichens	-							-	-	-		-		-			-			-	0/0
Moss	-			-	-			-	-				-				-			-	0/0
[illegible]							-	-	-	9	3	[illegible]		4	4	1	-	2	5	4	2.9/55
Ag [illegible]	10	15	[illegible]	3			20	14	-	3	7	7	16	26		2	7	14	21		11.1/90
Ag [illegible]						[illegible]		-	4	-		-	-	-	2	5	14	6	2	-	2.2/45
[illegible] Te							5	13	16	2	8	2	2	-	8	7	-	4	-	14	4.6/70
[illegible]		5		2			5	-	-	-		3	6	3	4	-	5	5		-	2.3/45
[illegible]							-	-	10	-		3	7	10	12		3		-		4.7/60
[illegible]	-	3			[illegible]	[illegible]	16	9	-	4	3	4	4	11	1	15	-	12	5	-	[illegible]
[illegible]	-						-	-	-	-	-		-	-			-	-	-		1.1/[illegible]
[illegible]								12	1		-		-	-			-	-	5		1.0/20
Ta O[illegible]	-	-	-	-	-		3	2	t	-	-					4	-	-	-		0.9/20
Da[illegible] Carfota	-	-	-				2	-	3	-	-					2	-			-	0.5/20
Cord [illegible]																			7	-	0.4/5
[illegible]							-	-	-	-	5	-	2	-			-	-		-	0.4/10
[illegible]							-	-	-	-	-	-	-	-	-		-	-		-	0.1/5
S[illegible]											3	-	-	-	-		-				0.3/5

Topography:	Configuration:	Coverage Class	Range	Midpoint
1. ridge	1. convex	1	0- 5%	2.5%
2. upper slope	2. straight	2	5- 25%	15.0%
3. mid slope	3. concave	3	25- 50%	37.5%
4. lower slope	4. undulating	4	50- 75%	62.5%
5. bench or flat		5	75- 95%	85.0%
6. streambottom		6	95-100%	97.5%

Appendix E. Vegetation transect slides, Belt-Sand Coulee area, Montana, 1980.

Appendix F. Comprehensive species list of vascular plants, Belt-Sand Coulee area, Montana, 1980.

GRASSES AND GRASS-LIKE PLANTS

Agropyron caninum	bearded wheatgrass
Agropyron repens	quack grass
Agropyron smithii	western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Aristida longiseta	red threeawn
Avena sativa	common oat
Bouteloua gracilis	blue grama
Bromus inermis	smooth brome
Bromus japonicus	Japanese brome
Bromus tectorum	cheatgrass brome
Calamagrostis montanensis	plains reedgrass
Carex eleocharis	needle-leaf sedge
Carex filifolia	threadleaf sedge
Echinochloa crusgalli	barnyard grass
Festuca idahoensis	Idaho fescue
Hordeum jubatum	foxtail barley
Juncus spp.	rush
Koeleria cristata	prairie junegrass
Phleum pratense	timothy
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Poa sandbergii	Sandberg's bluegrass
Spartina pectinata	prairie cordgrass
Stipa comata	needle-and-thread grass
Stipa viridula	green needlegrass
Triticum aestivum	wheat
Vulpia octoflora	six weeks fescue
Equisetum spp.	horsetail

FORBS

Achillea millefolium	western yarrow

Allium textile	textile onion
Amaranthus graecizans	tumbleweed amaranthus
Antennaria spp.	pussy-toes
Apocynum spp.	dogbane
Arabis holboellii	Holboell's rockcress
Artemisia absinthium	absinthium
Artemisia dracunculus	dragon sagewort
Artemisia ludoviciana	cudweed sagewort
Arctium minus	common burdock
Aster chilensis	creeping aster
Aster falcatus	creeping white prairie aster
Astragalus miser	pea
Astragalus spp.	pea
Balsamorhiza sagittata	arrowleaf balsamroot
Besseya wyomingensis	kittentail
Camelina microcarpa	hairy falseflax
Campanula rotundifolia	harebell
Cerastium arvense	field chickweed
Chenopodium album	lambsquarter
Chrysopsis villosa	hairy goldenaster
Cicuta douglasii	western water-hemlock
Cirsium arvense	Canada thistle
Cirsium undulatum	wavy-leaved thistle
Cirsium vulgare	bull thistle
Clematis ligusticifolia	western clematis
Conringia orientalis	hare's-ear mustard
Comandra umbellata	bastard toad-flax
Convolvulus arvensis	bindweed
Coryphantha vivipara	pink pinchshion cactus
Cryptantha interrupta	bristly cryptantha
Cynoglossum officinale	common hounds-tongue
Delphinium bicolor	little larkspur
Erigeron spp.	fleabane
Euphorbia spp.	spurge
Fragaria vesca	strawberry
Galium boreale	northern bedstraw

Gaura coccinea	scarlet gaura
Geum triflorum	prairie smoke
Geranium viscosissimum	sticky geranium
Glycyrrhiza lepidota	licorice
Grindelia squarrosa	curly-cup gumweed
Haplopappus spinulosus	spiny goldenweed
Helianthus annuus	common sunflower
Heuchera spp.	alumroot
Kochia scoparia	summer cypress
Kuhnia eupatorioides	false-boneset
Lactuca pulchella	blue lettuce
Lactuca serriola	prickly lettuce
Lepidium densiflorum	prairie pepperweed
Linum perenne	flax
Liatris punctata	dotted blazingstar
Linaria vulgaris	butter and eggs
Lithospermum arvense	corn gromwell
Lupinus sericeus	silky lupine
Lygodesmia juncea	skeletonweed
Medicago sativa	alfalfa
Melilotus officinalis	yellow sweet clover
Monarda fistulosa	wild bergamot
Opuntia fragilis	brittle pricklypear
Opuntia polyacantha	plains pricklypear
Oxytropis spp.	pointloco
Penstemon spp.	penstemon
Petalostemon purpureum	purple prairie-clover
Phlox hoodii	Hoods Phlox
Polygonum spp.	knotweed
Potentilla spp.	cinquefoil
Psoralea esculenta	breadroot scurfpea
Psoralea tenuiflora	slimflower scurfpea
Ratibida columnifera	prairie coneflower
Rhus radicans	poison ivy
Rumex acetosella	sheep sorrel
Rumex crispus	curly dock
Salsola kali	Russian thistle

Senecio spp.	groundsel
Sisymbrium loeselii	smallpod tumblemustard
Solidago missouriensis	goldenrod
Solidago rigida	stiff goldenrod
Sphaeralcea coccinea	scarlet globemallow
Tanacetum vulgare	common tansy
Taraxacum officinale	common dandelion
Thalictrum occidentale	western meadow rue
Thermopsis rhombifolia	prairie thermopsis
Trifolium spp.	clover
Tragopogon dubius	common salsify
Typha latifolia	cat-tail
Verbascum thapsus	mullein
Vicia americana	American vetch
Viola spp.	violet

SUBSHRUBS

Artemisia frigida	fringed sagewort
Xanthocephalum sarothrae	broom snakeweed

SHRUBS

Amelanchier alnifolia	serviceberry
Artemisia cana	silver sagebrush
Prunus virginiana	chokecherry
Rhus trilobata	skunkbush sumac
Ribes setosum	redshoor gooseberry
Rosa arkansana	Arkansas rose
Symphoricarpos occidentalis	snowberry

TREES

Crataegus douglasii	black hawthorn
Elaeagnus angustifolia	Russian olive
Fraxinus pennsylvanicas	green ash
Picea glauca	white spruce

Pinus ponderosa	ponderosa pine
Populus deltoides	plains cottonwood
Populus tremuloides	quaking aspen
Salix spp.	willow

Appendix G. Summary of transects and mine designation by vegetation type, Belt-Sand Coulee area, Montana, 1980.

Transect Designation	Montana Designation	Vegetation Type
Belt		
A	7-5	RHTR/AGSP
B	7-3, 4	RHTR/AGSP
C	7-6	MIXED SHRUB/POPR
D	7-19	SYOC/POPR
E	7-26	MIXED SHRUB/POPR
F	7-24, 34	RHTR/AGSP
Sand Coulee		
G	7-17, 46, 47	MIXED SHRUB/POPR
H	7-45	SYOC/POPR
I	7-36	MIXED GRASSLAND
J	8-37, 38	MIXED GRASSLAND
K	7-20	MIXED GRASSLAND
L	7-45, 28, 29	SYOC/POPR
M	7-13, 14, 15	MIXED SHRUB/POPR
N	7-7, 9, 10, 11	RHTR/AGSP
O	7-12, 8, 43	RHTR/AGSP
P	7-27, 48, 49	MIXED SHRUB/POPR
Q	7-16, 40	SYOC/POPR
R	7-41, 42	MIXED GRASSLAND
S	7-1, 2	MIXED GRASSLAND

VIII. Exhibits

Exhibit B. Soil Conservation Service soil series survey map, Belt-Sand Coulee area, Montana, 1980.

See Map Case B

Exhibit C. Vegetation transect locations mapped on U.S.G.S. base acetate overlays, Belt-Sand Coulee area, Montana, 1980.

See Map Case C

AGRICULTURAL PRACTICES

THE POTENTIAL EFFECTS OF AGRICULTURAL PRACTICES ON ACID MINE DISCHARGE IN THE BELT-SAND COULEE AREAS

3. Potential effects of agricultural practices on acid mine discharge

Contents

Tables

Figures

I. INTRODUCTION

The crop-fallow rotation system of dryland agriculture practiced in the northern Great Plains region is known to contribute to land management problems in the form of saline seeps (Bahls and Miller, 1975, Miller et al., 1980). Efforts to conserve soil moisture through fallowing result in the accumulation and movement of water high in dissolved salts from the root zone to local discharge areas. Hypothetically, acid mine drainage could similarly originate from aquifers located in the strata above and peripheral to abandoned mine sites: excess moisture which has been exposed to oxidized pyrites in old shafts emerges at ground surface in a highly acidified state.

This report attempts to establish a correlation between discharging mines in the Belt and Sand Coulee areas and current land use practices utilizing logic developed in saline seep research. It also explores alternative cropping practices that can be used to reduce the deep percolation of excess water. A pilot project recommendation has been developed to provide site-specific information necessary to implement this method as an abatement technique.

II. METHODS

A literature review was undertaken to investigate alternative land management practices as potential abatement techniques in controlling acid mine discharge. In the course of the investigation, the following sources were utilized: Montana State Library, Montana State University, state and county Soil Conservation Service offices, state and county Agricultural Stabilization and Conservation Service offices, County Extension Services,

the Old West Regional Commission (ERIS), Butte Mineral Research Center, Montana Bureau of Mines, Cascade County Assessor, Conrad Triangle Conservation District and the U.S. Bureau of Mines.

Numerous interviews were conducted with farmers, researchers, state and federal employees, and personnel from private organizations.

III. LITERATURE REVIEW

A. Correlation between current agricultural practices and acid mine discharge

1. History of agricultural practices and saline seep

The crop-fallow system of farming has been used extensively for soil moisture conservation in the production of small grains on nonirrigable acreages in the northern Great Plains region.

The crop-fallow system was introduced in the 1930's. Land cropped under this method is left unplanted for a season to increase stored soil moisture. After the land is left idle for a year, it is planted to a small grain of choice. With the advent of efficient farming equipment and chemical weed control, it has been possible to annually commit more and more acreage to production. Fallowing provides other benefits aside from increasing moisture to assure profitable crop yields: organic matter is converted to available nitrate-nitrogen during the fallow period; cultivation provides an effective means of weed control; there is a more uniform distribution of labor and power; and income flow is stabilized (Stauber and Burt, 1971). Concomitant with the extensive plowing of native grassland has been the development of saline seep.

Saline seep is known to be a highly destructive force on soil and water

resources of the northern Great Plains region. Defined as "recently developed saline soils in nonirrigated areas that are wet some or all of the time. . .and where crop or grass production is reduced or eliminated", saline seeps have caused severe economic losses to farmers and ranchers (Bahls and Miller, 1973).

The formation of saline seeps in much of this region is attributable to both the geological circumstances of the northern Great Plains and current agricultural practices. Excess water from several sources moves below the root zone, picks up magnesium, sodium, and calcium salts in glacial till, and forms a perched water table on an impermeable material. This water, high in dissolved salts, eventually moves downslope, resurfacing in swales and low areas as a saline seep (See Figure 1).

Other sources of excess water include: periods of high precipitation, poor surface drainage, snow accumulation, gravelly and sandy soils, drainageways, leaking ponds and dugouts, unplugged flowing seismograph bores, roadbeds above natural drainways, and combinations of these sources (Brown, undated).

Water readily percolates through the soil profile in fallow-systems because active plant growth is prevented for a major portion of each two year period (Ferguson, 1979). In this manner, water moves below the root zone when field capacity is exceeded. This fact has been reported by several investigators (Black et al., 1974; Greenlee et al., 1968; Luken, 1962).

In a study conducted by Halvorson and Black (1974), 18 percent of total

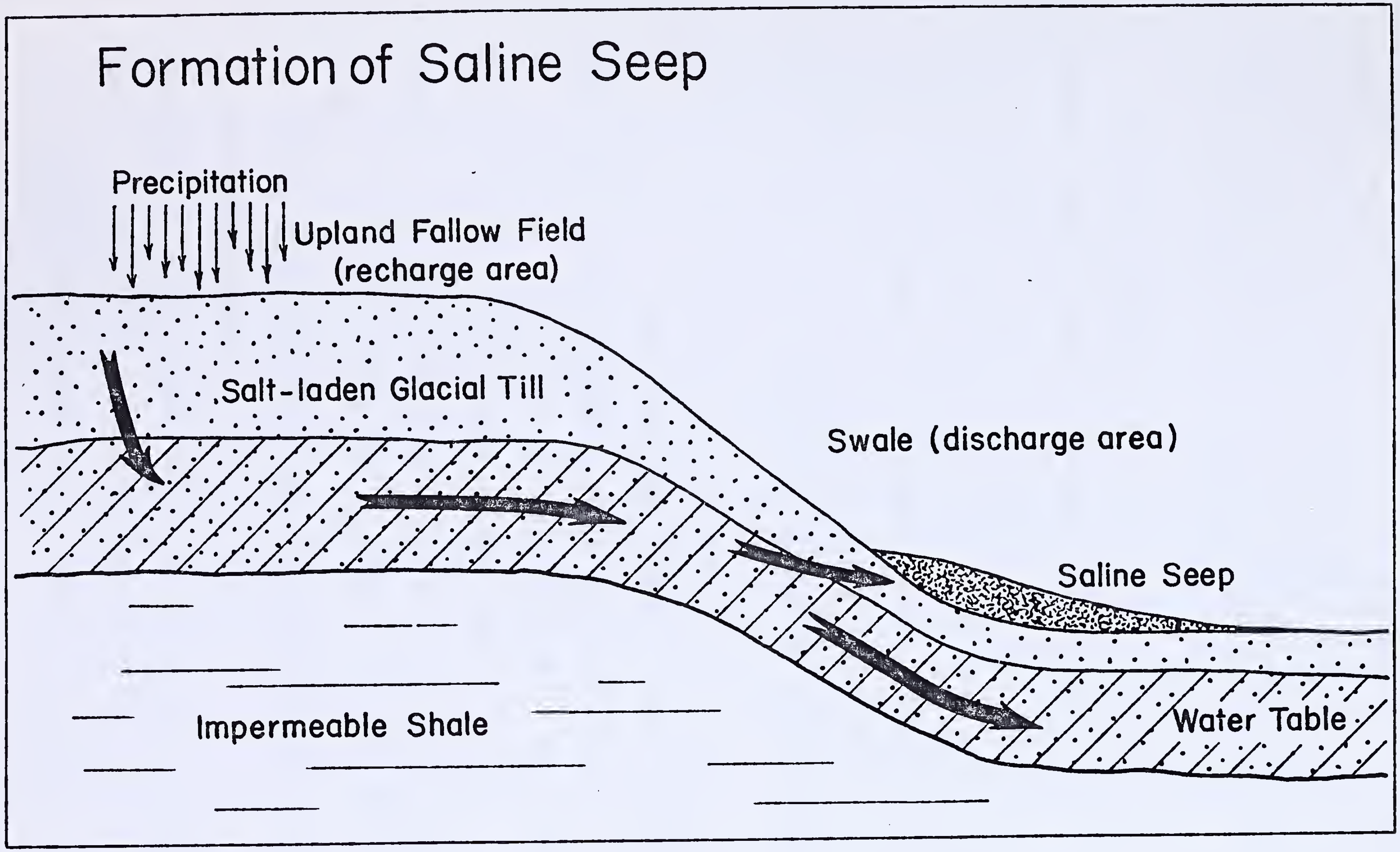

Fig. 1. Saline seep formation, from Banls and Miller (1975).

precipitation received was stored during a 21-month fallow period. The remainder was lost to evaporation, transpiration by weeds, surface run-off, and deep percolation. Precipitation received in the period of time between harvest and spring planting (before crop water use was significant) contributed greatly to deep percolation.

2. Acid mine discharge

Geologic formations and arrangement of strata vary from area to area, but the method of saline seep development remains essentially the same: excess moisture moves vertically beyond the root zone through a permeable layer to accumulate on an impermeable layer. This moisture eventually reaches the soil surface and evaporates. What is left behind are dissolved salts that have been picked up while passing through materials high in natural soluble salts.

In the case of acid mine drainage in the Belt-Sand Coulee area, excess water moves downward through sedimentary overburden until it reaches a less permeable black shale underlying the coal. This groundwater then travels laterally along the coal seams until it emerges at the ground surface. The water discharged at the portal has been exposed to oxygen and pyrites in the mine shafts which causes it to become highly acidic.

In the Belt-Sand Coulee area, the impermeable layer is contained within the Morrison Formation (Jurassic), which consists of 50 to 250 feet of mudstone. It also contains lenses of limestone, sandstone, coal and shale. The upper Morrison consists of black shale containing coal which ranges from a few inches to 12 feet in thickness. Coal may occur

in one to three benches separated by shale, sandstone, or siltstone partings.

The permeable overburden is characterized by the Kootenai Formation (Cretaceous) which overlies the Morrison and is 400 to 500 feet thick. It consists of a basal sandstone unit overlain by mudstones containing numerous limestone and sandstone lenses (Silverman and Harris, 1967).

The basic assumption is that excess moisture associated with both saline seep and acid mine drainage is locally derived, and is not part of a regional flow system. Saline seep research emphasizes that this is the case: on the Highwood Bench near Fort Benton, there is a close correspondence between local precipitation and water table fluctuations. Groundwater tables in the Missouri River Basin (where 90 percent of eastern Montana's dryland cultivation occurs) are rising at the rate of four to ten inches a year. The basin itself is cumulatively storing more water than it did prior to fallow cropping (Bahls and Miller, 1975).

B. ALTERNATIVE AGRICULTURAL PRACTICES

Considerable research has been conducted in the last decade involving the reclamation and control of saline seep. Numerous investigators have published papers and private operators have organized to provide solutions to a land management problem that is consuming thousands of once-productive acres.

These solutions address conservation and crop production practices, and mechanical practices that have been successfully employed on recharge areas to reduce the deep percolation of excess moisture. Many of these

practices have direct application to acid mine drainage situations in the Belt and Sand Coulee areas. Though not a problem on the same scale as saline seep, acid mine drainage has had a significant impact on the land and water resources of these localities.

In order to control the discharge of acid mine water, the recharge area must be located and delineated. A distinction should first be made concerning the source of excess water at the recharge site: if fallow farming or sandy and gravelly soils are promoting excess moisture below the root zone, more intensive cropping practices can be adopted to control the discharge. If the source of excess water is due to poor surface drainage, snow accumulation, or constructed ponds or drainways, mechanical practices must be employed to control the discharge (Brown et al., undated).

1. Alternative cropping sequence

Farming more intensively or "flexible cropping" is an alternative to fallowing which incorporates a choice to seed or not based on readily available data. A farmer can plant when there is adequate stored soil moisture in the root zone and a favorable probability of growing season precipitation to produce a satisfactory yield, or he can opt to fallow when these factors are unfavorable. (Continuous cropping is the practice of planting each spring, regardless of moisture conditions).

Advantages to flexible cropping include using 80 percent of the available moisture (as opposed to using 40 percent with fallow systems), growing more crops per acre, and reducing fuel bills per unit of crop. Disadvantages include an intensified land management program to deal with weeds, volunteer grains, increased disease, and soil nutrient depletion of

fertilizers (U.S.D.A. undated).

Stored soil moisture can be calculated by determining the depth of moist soil. Soil tubes, augers, and probes are used to estimate moist soil depth. Each field is probed at several representative locations to obtain an average reading. Average depth is then multiplied by the amount of plant available water per foot of depth (See Table 1).

Plant available water is a function of soil texture. Sandy and gravelly soils have a low water holding capacity and are unable to store much water in the root zone. Coarse-textured soils are able to retain an average 0.8 inches of available water per foot of moist soil depth. A minimum moist soil depth of 30-40 inches is necessary for seeding spring grain. These types of soils should be recropped most of the time.

Sandy loam and loamy soils contain an average 1.5 inches of available water and require a depth of 20-30 inches for seeding. Silt loam and clay soils hold 2.0 inches of available water; 15-24 inches of moist soil are necessary for seeding on these soils (Alberta Department of Agriculture, 1976).

Dryland farming requires an average 8-10 inches of stored soil water and growing season precipitation for successful recropping. Most areas in the northern Great Plains receive only six to seven inches of precipitation; this means two to four inches must be replaced with stored soil moisture.

Growing season rainfall probability tables have been compiled that correspond to variations in seeding dates for given areas in Montana

Table 1. Plant available water estimates in inches by soil texture.

Soil Texture Class	Plant Available Water-Inches per Foot of Soil
Sands and fine sands	0.75
Very fine sands, loamy sands, and loamy fine sands	1.00
Sandy loam, fine sandy loam, clay loam, sandy clay loam, silty clay, clay and heavy clay	1.50
Loam, very fine sandy loam, silt loam, silts and silty clay loam	2.00

Source: U.S.D.A. 1980. Flexible cropping systems, Soil Conservation Service Bozeman, MT. 6 pp.

(Caprio, undated). For example, there is a 79.5 percent probability of receiving five inches of precipitation between April 1 - June 30 at Fort Benton, Montana.

Once plant available water and expected seasonal precipitation figures are known, estimated yields of spring wheat and barley can be made using existing tables compiled by Bauer (1972) and Brown (1971).

The decision to plant or fallow can be made by comparing yield estimates with average fallow yields. If the estimated yield is 60-75 percent of average fallow yields, the chance of a satisfactory yield is good. If the estimate is less than 60 percent of average fallow yields, the land should be fallowed. If an operator fallows land with limited stored soil moisture in the spring, it will be possible to store enough moisture for the following season (Brown et al. undated).

Flexible cropping requires an intensive level of management and special consideration for factors such as tillage practices, weed problems, fertilizer requirements, plant disease, and selection of alternate crops for water conservation and erosion control.

Retention of soil moisture in the fall and winter periods increases chances of successful recropping the next spring. Snow can be trapped by leaving maximum-height stubble in fields after harvest. Brown (undated) reports that standing stubble consistently traps more snow and gains one to three inches more soil moisture than flattened or incorporated stubble.

Flexible cropping systems lend themselves well to no-till planting. Enough crop residue should be left on the soil surface to control erosion by wind and water.

Elimination of after-harvest weeds and volunteer grain is essential to reduce their further production and to avoid losing soil moisture. Herbicides and cropping sequences can be selected that will help control these populations. Glyphosphate and 2,4-D are common herbicides sprayed on affected fields. Different herbicides can be used to advantage in conjunction with rotation of various crops.

If weed or volunteer crop populations are great enough, stubble can be undercut with an implement that still leaves stubble standing for snow catchment purposes.

Increased soil nutrient needs inherent in flexible cropping require higher rates of fertilization. Without adequate fertilization, wheat yields remain low even if plant available water is sufficient. A minimum quantity of soil nitrogen is necessary to achieve a given yield.

Fertilization can increase rooting depths from one to two feet and water use from one to three inches. Wheat and barley yields both increase substantially with each inch of extra water use (Brown, undated).

Soil testing can be conducted to determine appropriate application rates. Fertilizer guides are available from the Montana Cooperative Extension Service.

2. Alternative crops

Alternate crops such as hay and oil seed varieties should be included in each crop rotation. They serve to control plant diseases and weeds. If crops are grown continuously, diseases such as cephalsporium, root rot, wheat streak mosaic, and bacterial diseases will quickly proliferate.

Principal crops currently grown in the Belt-Sand Coulee areas include winter wheat, barley, oats, spring wheat, and hay. According to the Agricultural Stabilization and Conservation Service in Cascade County, the area west of Belt is continuously cropped (cropped each season). Farmland east of Belt is summer fallowed. Farmers in the Sand Coulee, Centerville and Tracy areas employ continuous cropping methods; Cottonwood Creek and Number Five Coulee are summer fallowed.

Land management and cropping practice alternatives to the current small grain fallow system exist that may serve to retard pollution of underground water.

Barley, oats, spring wheat and winter wheat have average rooting depths of four to six feet. Deep rooted perennials such as alfalfa, sainfoin, tall wheatgrass and Russian wildrye can be planted at both recharge and discharge sites to dry out deeper subsoils. They can also be planted successfully on areas and soils where small grain production is marginal.

Rooting depths for 11 varieties of alfalfa planted in Spring, 1976 at Fort Benton ranged from 12-20 feet over a four year period. Hay yields varied from 3,240 lbs/acre to 4,920 lbs/acre. Cumulative soil water extraction rates (the amount of water removed from the soil over the

four year period) were 19.9 to 33.3 inches. In other experiments, alfalfa lowered water table levels by 11 feet over a five year period.

If the soils and parent material at the recharge and discharge sites are deep enough to support a deep-rooted perennial, one should be planted. If allowed to grow for four to five years, the vegetation should dry the soil profile out. Following plowdown, a flexible cropping system should be utilized.

Other forage species can be seeded to help reduce high levels of soil moisture. These include needle grass, fescue, basin wildrye and wheatgrasses. In a soil extraction study conducted in 1976 at Fort Benton (similar to the seeding of alfalfa cited previously) rooting depths of forage grasses ranged from 9-18 feet and forage yields varied from 2,460 lbs/acre to 4,800 lbs/acre. Cumulative soil water depletion averaged from 11.4 to 22 inches (Brown and Zizz, 1979).

Deep-rooted oil seed crops such as safflower, sunflower, mustard, flax and rape can be selected as alternatives to cereal grains which have shallower rooting depths and hence use fewer inches of soil water.

The inclusion of hay or oil seed crops in a rotation will help maintain soil organic matter and improve tilth. When used in conjunction with herbicides, they also aid in breaking weed and disease cycles.

Rooting depth and soil water use data of ten crops seeded on fallow fields at Fort Benton are presented in Table 2 for comparison.

Native grass ecosystems are efficient users of water that restrict deep

Table 2. Yield, oil content, rooting depth and soil water depletion of 10 crops seeded on fallow at Fort Benton, Montana, 1976-1979.

Crop	Yield Lbs/A	Oil Content %	Root Depth Feet	Soil Water Depletion Inches	1976-1979 Yield Range Lbs/A
Safflower	1559	42.0	7.0	10.4	1141-2302
Sunflower	1211	48.0	5.8	7.5	1025-1481
Oriental Mustard	1142	36.0	5.0	7.1	718-1970
Flax	891	41.2	5.0	6.8	772-960
Yellow Mustard	858	26.2	4.5	6.5	562-1387
Turnip Rape	800	37.0	5.0	6.8	457-1144
Brown Mustard	790	30.9	5.0	6.6	565-1230
Argentine Rape	568	38.2	4.3	7.2	288-1110
For Comparisons					
Winter Wheat	3005	-	5.6	7.1	2057-3700
Barley	2912	-	4.8	6.4	2048-3663

Source: Brown (undated)

vertical percolation of moisture. Infiltration studies conducted by Donnahue and Ashley (1973) on the Highwood Bench demonstrated that water penetrating the ground surface in sod situations is subject to greater horizontal distribution than in fallow situations. The humus layer in sod acts as a moisture holding reservoir that allows use of water by plants before loss to deep percolation to below the root zone. The humus layer also prevents erosion by wind and water from occurring.

Information regarding proper plant species selection, cultural practices

(seedbed preparation, planting and management), seed availability and appropriate rotation sequences is available from the Montana Cooperative Extension Service.

3. Mechanical practices

Mechanical practices can be implemented to control excess water and reclaim land disturbed by acid mine drainage. These practices work to reduce the infiltration of excess water.

Grass waterways, dikes, and terraces can be established at recharge sites on poorly drained areas where ponded water collects. It is possible to effectively route runoff to areas having higher drainage potential or more water-tolerant vegetation species.

Observation wells should ideally be located at strategic locations to monitor fluctuations in the water table. Cropping practices can then be changed to reflect the rise or fall of water levels.

Excess accumulation of snow through the use of barriers (snow fence, windbreaks, landforms) should be avoided, where possible. Deep-rooted plant species can be planted at these types of sites.

Tile drains can be placed upslope from a known discharge area to intercept moisture before it comes in contact with oxidized pyrites to form highly acidified water.

C. Cost considerations

Grain producers are interested in cropping sequences that produce a high average net return over a period of several years. Flexible cropping

utilizes information regarding previous land use, long-term average yields and measurable soil moisture to predict the probability of successfully producing a crop. In this situation, control is exercised over subsequent yields and returns (Stauber and Bert, 1971).

Economic tradeoffs must be evaluated when choosing to re-crop or fallow. (The decision to plant or not is, of course, based on soil moisture at planting time). Re-cropping provides a relatively high immediate return, but at the risk of being at a moisture disadvantage the next year. Fallowing yields a negative immediate return and results in more favorable moisture conditions for the next year.

It is difficult to estimate benefits realized from acid mine drainage abatement due to re-cropping. However, the value of acid drainage abatement from re-cropping should exceed or be equal to the reduced cost of not cropping (Quenomoen, undated).

TAP, Inc. (1980) estimated the foregone revenue attributed to cropland not in production due to mine-related activities in the last forty years at $53,964 in the Sand Coulee area. No figures are available for foregone revenue from land lost solely to acid mine discharge.

IV. RECOMMENDATIONS

The assumption that fallow cropping enhances acid mine discharge is precisely that: an assumption. In order to substantiate a correlation between the deep vertical percolation of water due to fallow systems and acid discharge, it would be useful to develop a working model that incorporates an alternative cropping sequence. If this theory is subsequently proven as valid, the alternative system can then be evaluated for cost effectiveness in comparison to other abatement techniques.

The selection of a potential study site should be based on: 1) the identity of an actively-discharging mine; 2) the location of a suspected recharge site above an adit that is currently utilizing a fallow system; and 3) the designation of a cooperating landowner.

There are two sites which present themselves as possibilities for further investigation that meet the first two items of criteria presented above: 1) State designation D7-49 (SCM 2) south of Sand Coulee, SENE Section 23 T19N R4E and 2) State designation D7-20 (SCM 4) west of Giffen Corners, SWNE Section 14 T18N R4E.

Both mines are actively discharging acidic water and both possess potential recharge sites (in the form of fallow fields) above the adits. Land ownership varies from discharge site to recharge site at each of the mines; for the purposes of this report, no effort has been made to locate cooperating landowners.

Prior to implementing any changes in land management, an in-depth description and inventory of the study area should be conducted. Geophysical techniques can be utilized to supplement test hole data to accurately delineate both the recharge and discharge areas. (Simple observation and use of a soil probe can often be an effective means of determining recharge and discharge areas). The source of recharge can be located using a four probe system of gridding the upslope edge of the discharge area to determine direction of flow into the discharge.

A total hydrologic assessment should include the drilling of test holes to determine depth of bedrock, nature of the material, and watertable depth. Aquifer tests can be conducted that will reveal information about permeability,

transmissibility, and effective porosity of the medium. Wells should be established at crucial locations to record water level fluctuations with time and to ascertain direction of groundwater flow.

Surface water samples should be collected and analyzed, and a small watershed should be instrumented to obtain an accurate water budget. The rate and quantity of water moving through the soil profile can be determined by infiltration tests.

Old well logs and meteorological data will contribute to knowledge about past hydrologic activity. In the characterizing of substrata, the extent of old underground mine workings should be described as completely as possible to aid in the assessment of water movement.

Following preliminary investigations, an alternative cropping sequence can be established that is amenable to that particular operation. The selection of crops to be planted will be based on water extraction rates, suitability to the area in question, soil chemistry and fertility levels, weed and disease control, tillage practices, available equipment, market considerations, and of course, available soil moisture.

Appropriate mechanical practices mentioned previously may also be considered for control of excess water.

Soil moisture movement, watertable fluctuations and meteorological events should be monitored over a period of time considered to be adequate to conclusively assess the effects of changeover. If excess moisture is reduced and the character of acid discharge changes due to the more efficient use of soil water, the procedure may find application elsewhere

as an abatement technique. A comparative cost analysis with other abatement techniques should be conducted at the conclusion of the model study period to determine its effectiveness.

The Triangle Conservation District at Conrad, Montana has developed a similar program for saline seep control and reclamation. Operators voluntarily apply for assistance through the Conservation District, and participate in the investigation and evaluation of the seep area. They are partially responsible for maintaining watertable records and designing a plan for control.

V. CONCLUSIONS

1 - Efforts to conserve soil moisture in much of the northern Great Plains region has resulted in the accumulation and movement of water high in dissolved salts from the root zone to local discharge areas to surface as saline seeps.

2 - Excess water percolating below the root zone which has been exposed to air and mineral pyrites in mine shafts emerges at ground surface in a highly acidified state.

3 - Excess moisture associated with both saline seep and acid discharge is locally derived.

4 - Acid mine drainage has an impact on land and water resources of the Belt-Sand Coulee areas.

5 - Land management and cropping practice alternatives to the current small grain fallow system exist that may serve to retard pollution of underground water, through the more efficient use of soil moisture.

6 - Economic tradeoffs must be evaluated when deciding whether to change to a more intensive cropping system or not. The benefits of acid discharge abatement should be figured into this decision.

7 - The correlation between current agricultural practices and their effect on acid mine discharge must be substantiated through on-site research.

8 - There appears to be support in the Belt-Sand Coulee communities for mine reclamation projects in general, and changes in current agricultural land practices that may be polluting groundwater systems.

Willingness by area producers to change farming habits was reflected in results obtained in a questionnaire distributed by TAP, Inc. in Belt and Sand Coulee. Respectively, 65 percent and 64 percent of the respondents indicated a desire to participate and have direct input in mine reclamation projects.

It has been estimated by Brown (1981) that the Conrad Triangle Conservation District Saline Seep Control program has an 80 percent rate of acceptance by area grain farmers.

Grain producers in the northern Great Plains have been managing soil moisture for the past 40-50 years. There is every reason to believe that the trend by individual producers in the area is to adopt more intensive soil moisture management techniques, especially when the economic incentive to do so exists.

Funding opportunities for this type of project may be available through application to a local Conservation District Office for RAMP assistance (Anseth, pers. comm.).

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AIR QUALITY TECHNICAL REPORT

AIR QUALITY
TECHNICAL REPORT

SAND COULEE / BELT AREAS

4. Air quality technical report

Contents

I. AIR POLLUTION APPRAISAL

On January 13, 1981, after an unusually long period of unseasonably dry and warm weather, the abandoned mine sites and ash dumps in Sand Coulee, Tracy, Centerville, Stockett, and Belt, Montana were visited and analyzed. The visit was greatly facilitated by having Mr. Duane Noel, soil scientist on the project, as a tour guide. Three types of mining wastes were observed: mine tailings, stockpiled coal, and boiler ash (cinders).

Erosion over geological time has produced valleys and ridges. Coal seams were naturally exposed about one-third of the way up the ridges. Later the seams were entered by mines in many places mostly on the east and west slopes of the ridges. Tailings were left below the adits. In a few cases, coal piles were left near the adits. Ash from consumed coal have been left in unsightly piles in close proximity to residences.

Samples of the material were taken from the top one-half inch of the Heal Tailings Pile and the Third Finger Ash Pile at Sand Coulee. The material was so "loose" it could be scooped up like dry sand on a beach. Screen analysis of the ash showed the largest pieces to be about the size of peanuts; 32 percent of the material passed a #20 screen (850 mm), 3 percent passed a #140 screen (106 mm), and 2 percent passed a #200 screen (75 mm). Screen analysis of the tailings showed a similar size distribution.

In Stockett and Belt, there are large exposed piles of ashes and cinders immediately adjacent to homes.

Tailings and ash are being used on private roads throughout the area. Public roads are using gravel. Farmers use the coal for their roads because it enhances the melting of snow in winter. They use the tailings for covering the ground when calves are young because of the very absorptive characteristics.

The prevailing winds are from the southwest during every month of the year. Winter has the highest average wind speed, about 15 mph, perhaps because of the chinook winds. Although the average wind speed is relatively high during all months, extremely strong winds (over 70 mph) are seldom observed. While sub-zero weather is experienced normally several times during a winter, the coldest weather seldom lasts more than a few days at a time, and is usually terminated by southwest "chinook" winds which can produce sharp temperature rises of 40° or more in 24 hours. As a result of recurring chinooks throughout the winter season, snow seldom lies on the ground for more than a few days. The average annual precipitation of 14.99 inches would normally classify the area as semi arid. However, of this total 10.19 inches falls during the months of April through September while only 4.80 inches fall during the months of October through March.*

As a result of this brief visual survey of the abandoned mines in the area of Sand Coulee, Tracy, Centerville, Stockett, and Belt, Montana,

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* Local Climatological Data, 1979, Great Falls, NOAA

our opinion of the air pollution potential is as follows:

1. The wind in the abandoned mine area is sufficiently strong to move almost all sizes of particles in the refuse materials.

2. The tailings and ash are unconsolidated and of such physical structure as to be ideal for movement by the wind.

3. Because of the large quantity of fines in the surface layer of the refuse material, it seems obvious that the material is now and has been transported by the wind for decades.

4. Apparently both the ash and tailings contain very corrosive and possibly toxic material that would be hazardous to the lungs of humans and animals.

5. Judging from the devastating effect of leachate on plant material, it would seem that refuse material blown on to nearby range land by the wind might be deleterious to the proper growth of range grass.

The questionnaire sent to residents and property owners in the area illustrated the following concerns about air quality:

Belt Eighteen respondents recognized an air pollution problem. Three thought it was significant. One felt that it could have affected their health.

Sand Coulee Four respondents recognized a small air pollution problem. Two felt their property had been affected. One thought it could have affected their health.

Stockett Three respondents recognized an air pollution problem. One thought it was small. None were concerned about their property but two thought there was a health problem. Because the two who mentioned health did not check the air pollution box, they may have been thinking about some other aspect of pollution.

Residents and property owners have lived with this problem for many years and have adapted to the environment. Although dust from mining waste must be evident, they obviously also observe dust from the many gravel roads in the area. Mining wastes remains have become a nearly free commodity and they have found uses for it even though they may not recognize its hazards.

Recommendations for solving the air pollution problem include:

1. Remove the ash, tailings, and coal piles. This can be done by putting it back in the mine or transporting it to a landfill.

2. Stabilize the polluting material. This would require leveling the piles and covering the material with sod or with a binding material such as lignin.

3. Educate the residents and property owners about the hazards of indiscriminate use of the mining materials.

II. AIR QUALITY MONITORING AT STOCKETT

Suspended particulate were measured in Stockett near residences during July and August, 1981 to determine particulate concentrations that are experienced by residents and to obtain data that might link the suspended particulate to the dust from the ash pile. A high volume sampler and a membrane sampler were borrowed from the Montana Department of Health and Environmental Services for use in the study. The high volume sampler was operated every three days and the membrane sampler every six days for the two month period. As a result, 18 samples of total suspended particulate were taken and 10 samples of particulate composition. Two TSP samples were invalidated.

The exposure of the samplers is pictorially presented in Figure 1. The high volume sampler was calibrated by Inter-Mountain Laboratories, Inc. and the results are presented in Figure 2. Calibration data for the membrane sampler were obtained from the Montana DHES. Data from the 4/13/79 and 1/22/80 calibrations were combined and analyzed by linear regression to obtain the following flow rate equation

$$Q = 0.00593\ (\Delta P) + 0.0190$$

where Q flow rate in cubic meters per minute

ΔP pressure difference indicated on the sampler

R, correlation coefficient, of 0.992

The membrane filters were placed in a flask, nitric acid was added, they were heated and refluxed through a condenser. The liquid

was then analyzed by atomic absorption spectrophotometry for arsenic, beryllium, cadmium, mercury, and zinc. After digestion was complete and during the spectral analysis, it was discovered that the flasks had been previously used to contain mercury sulfate. Normal cleansing in hydrochloric acid and deionized water is not adequate to remove mercury traces so the samples were inadequate for the analysis of mercury.

The total suspended particulate data and particulate composition data in units of micrograms per cubic meter are as follows:

Date	TSP	Filter	As	Be	Cd	Hg	Zn	Filter
7/03/81	63	1498	0	-.001	-.002	#	.009	1691
7/06/81	33	1499						
7/09/81	39*	1500	0	-.001	-.002	#	.002	1692
7/12/81	32	1501						
7/15/81	26	1502	0	-.002	-.005	#	.009	1693
7/18/81	53	1503						
7/21/81	85	1504	0	-.002	-.005	#	.019	1694
7/24/81	42	1505						
7/27/81	Inv.	1506	.003	-.001	-.002	#	.036	1695
7/30/81	43	1507						
8/02/81	45	1508	0	-.001	-.002	#	-.002	1696
8/05/81	47	1509						
8/08/81	64	1510	0	-.001	-.002	#	.019	1697
8/11/81	88	1511						
8/14/81	Inv.	1512	0	-.001	-.002	#	.022	1698
8/17/81	126 +	1513						
8/20/81	38	1514	0	-.001	-.002	#	.009	1699
8/23/81	63	1515						
8/26/81	104	1516	0	-.001	-.002	#	.016	1700
8/29/81	162	1517						

NOTES:
* Resident noted a big wind storm
\+ Sampler ran only 15 hours
\# Samples lost in the laboratory
Inv. Invalid

Soil samples were taken from the surface of the principal ash piles in Stockett and Belt, Montana, Figures 3 and 4, and analyzed for concentrations of Arsenic, Beryllium, Cadmium, Mercury and Zinc. Selenium and Lead analyses were not made because the WESTECH report of 10/80 on the Chemical Properties of Overburden Material in the Abandoned Mine Lands showed no concentrations of these elements. In Stockett the composite sample was taken from the highest (southern) point of the ash pile in a grid consisting of 22 spots. The soil was taken from the top one-half inch, screened with a #200 sieve (75 um) mixed in a bag. A similar sample was taken from the principal ash pile in Belt from the highest least-disturbed southern portion. The results of the analyses are as follows:

Site	Lab No.	Arsenic (ppm)	Beryllium (ppm)	Cadmium (ppm)	Mercury (ppm)	Zinc (ppm)
Stockett Ash Pile	8627	-0.01	-0.005	-0.01	0.052	3.72
Belt Ash Pile	8628	-0.01	-0.005	-0.01	0.032	0.94

The results from the three data sources did not permit conclusions to be drawn but the following general observations are made.

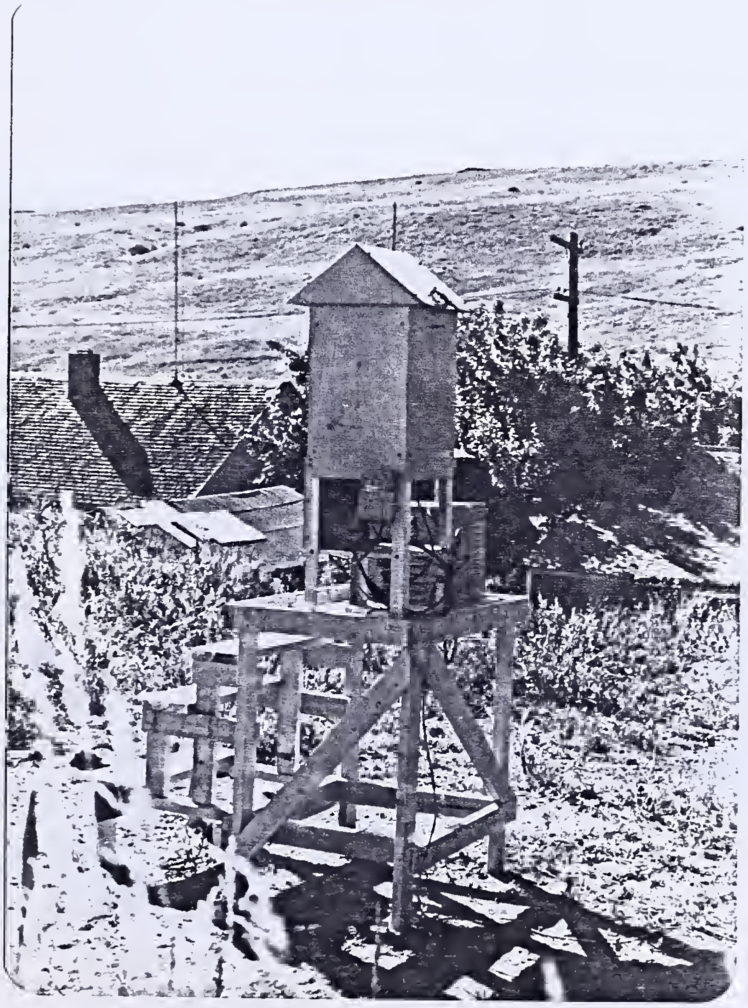
1. The TSP concentrations seem to be greater than one would expect for a pristine area and may be due to blowing ash and to the many gravel roads in the area. Ash is used for topping on some of the gravel roads according to residents.

2. On the day a resident reported a big windstorm, the TSP concentration was 39 as compared to an arithmetic average of 64 and a geometric average of 56 ug/m3.

3. Of the five trace elements tested, Arsenic, Beryllium, Cadmium, Mercury, and Zinc, only Mercury and Zinc were found in measurable quantities in the ash. The ash sample at Stockett had a larger Mercury and Zinc content than the ash sample from Belt.

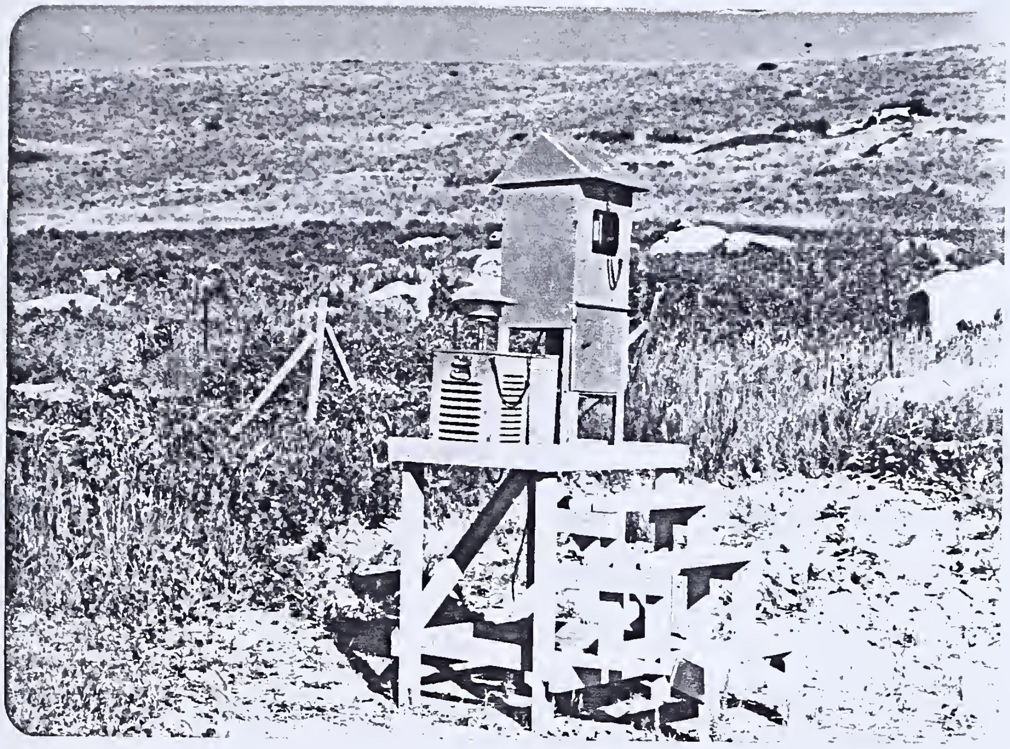
4. The composition of the suspended particulate qualitatively supports the thesis that ash is an important source of suspended particulate available to residents in respiration. This observation is based upon the presence of Zinc, the absence of Beryllium and Cadmium, and the general absence of Arsenic from the suspended particulate samples. It is regrettable that the observation cannot include the results of the mercury analysis.

Northerly View



Easterly View

Figure 1: Exposure of Sampling Equipment at Stockett



Westerly View

Southerly View

Figure 1: Concluded

Fig. 2

Inter-Mountain Laboratories, Inc.
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Tel. (307) 672-8945

Q.C. No.	1
REVISION	1
DATE	Sep 1980
PAGE	1 of 2

TRANSDUCER CALIBRATION

(High-Volume Air Sampler)

Calibrated by J. Scruggs
Client Westech
Date 7-1-81
Project No. AML - Stockett
Orifice No. 8101579
Sampler No.
Orifice Equation, Q_r = $.5090\ \Delta P^{.4878}$

Run	Plate No.	P1 (left)	P2 (right)	ΔP (inch water)	TR	Q_r* (m3/min)	Q_r** (m3/min)	ΔQ_r
1	open	4.7	4.7	9.4	48.0	1.518	1.509	+0.009
2	18	3.3	3.3	6.6	40.7	1.278	1.261	+0.017
3	13	2.8	2.8	5.6	37.8	1.179	1.162	+0.017
4	10	2.25	2.25	4.5	34.1	1.060	1.036	+0.024
5	7	1.55	1.55	3.1	29.3	0.884	0.873	+0.011
6	5	0.95	0.95	1.9	24.1	0.696	0.696	0.000

* Flow rate from orifice equation

** Flow rate from transducer equation

Slope, a = 0.034 intercept, b = -0.123

$TR_{0.7}$ = (0.7 - b)/a = 24.21 , $TR_{1.8}$ = (1.8 - b)/a = 56.56

Tranducer Equation, Q_r = a(TR) + b = 0.034 (TR)- 0.123

Correlation Coefficient 0.9997

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Q.C. No.	1
REVISION	1
DATE	Sept 1980
PAGE	2 of 2

TRANSDUCER CALIBRATION CURVE

CLIENT: Westech

HIGH VOLUME SAMPLER NO. ______

CALIBRATION DATE: 7-1-81

TRANSDUCER EQUATION $Q_r = 0.034(TR) - 0.123$

CORRELATION COEFFICIENT, R = 0.9997

Qref (English) $= Q_r \left[\frac{P}{T}\,\frac{536.7}{29.92}\right]^{\frac{1}{2}}$ Qref (Metric) $= Q_r \left[\frac{P}{T}\,\frac{298}{760}\right]^{\frac{1}{2}}$

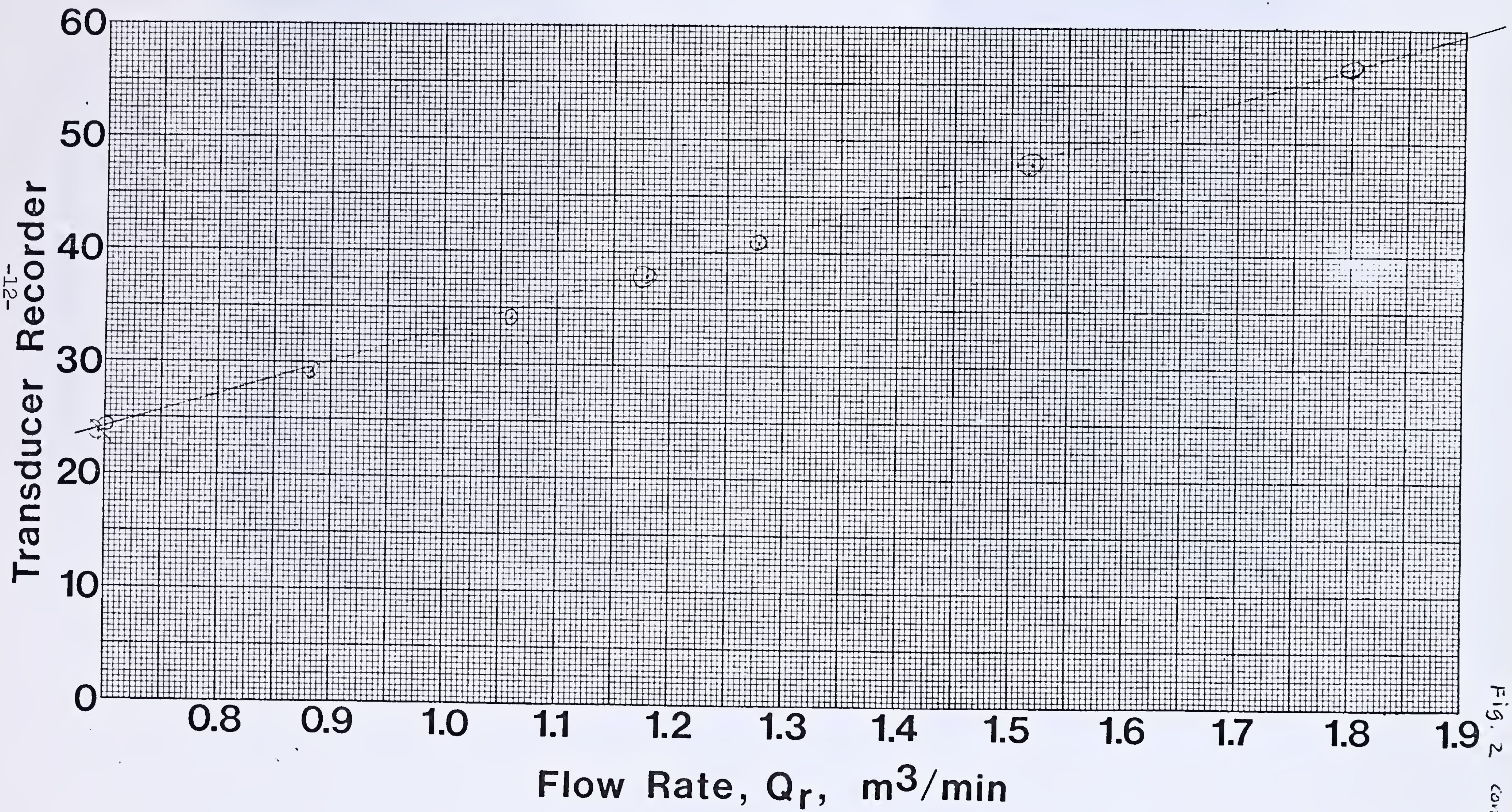

Fig. 2 concl.

a) Northwesterly View

b) Southerly View

Figure 3: Ash Pile Sampled in Stockett

a) Ash Pile Exposure

b) Sample Gathering

Figure 4: Ash Pile Sampled in Belt